METAL PROGRESS

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JULY, 1941 VOLUME 40 NUMBER 1

Cylindrical Mirrors of Steel Impart Fine Finishes on Inland Cold Finished Sheets

A GREAT door opens at one end of the Inland Strip Mill Roll Shop. A heavy truck backs in, and its load, a massive roll from an Inland Cold Strip Mill, is carried away in the cables of an overhead crane. A few moments later this roll is resting in the housings of a precision grinding machine, whose grinding wheel of selected grade lightly passes back and forth across the surface of the roll. Operating the machine is a skilled craftsman especially trained to judge fine roll finishes by sight, feel and use of extremely accurate gages.

A few minutes pass and lights begin to reflect on the newly ground roll surface. Gradually by skillful manipulation of machine and grinding wheel, this massive roll has become a revolving cylindrical mirror of steel.

Dozens of these rolls are ground each day for use in the Inland Cold Rolled Strip Mills. Extra rolls are always ready for quick change, to impart the fine surface for which Inland Cold Rolled Strip and Sheets are known wherever steel is used.

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METAL PROGRESS

July 1941 Volume 40 Number 1

STRENGTHENING ALUMINUM

for aircraft

structures

By Kenneth R. Jackman
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NEVER IN THE HISTORY OF AVIATION has there existed a greater need for light, strong, and economical materials. Engineers and designers must weigh the terms "light" and "strong" carefully in this day of high speed production. A needless pound of metal, unwisely placed, will not only reduce the pay load (or bomb and armament load in these troubled times) but must be carried on each errand, consuming horsepower with no effective returns. The third demand for "economical" design, not too costly, was more important in normal peacetimes; today we must economize, rather, on man-hours of labor.

A good strength-weight ratio is still a primary criterion of efficient aircraft design. Can we improve this ratio by substitution? Can we further increase the properties of aluminum or magnesium, which are even now light and strong? Let us tabulate the weight components of a modern four-engined airplane, say of 50,000 lb. gross weight. Its structural weight empty will probably be 27,000 lb., of which 11,000 lb. represents engines, propeller, accessories and non-structural furnishings. The remaining 16,000 lb. may be subdivided as shown in Table 1 (page 36). Obviously, the largest chance for savings is in the light alloys.

It must be emphasized that the weight distribution between drawn sections and extrusions or between forgings and castings varies with each manufacturer and in each model. Drawn sections have their advantages of local manufacture, versatility of gage, cheapness of manufacture, and possibilities of corrosion prevention by the use of alclad strip stock.

Now we can imagine ourselves in the position of the designer who is confronted with the task of lightening this structure, of modern design, clean externally and efficiently designed internally. Many forgings or castings might be changed to magnesium alloys, with some weight saving. Likewise these same forgings and castings, regardless of their material, undoubtedly have excess metal in odd corners. Here the metallurgist and test engineers can help.

Not much can be done to reduce the weight of the sheet that covers wing, fuselage and tail surfaces. The present trend is to use 24S-T alclad sheet, thereby eliminating most of the corrosion troubles by the pure aluminum external coating and yet retaining the enhanced core strength of 24S-T. Where the surface covering is in tension or shear some weight may be saved by substituting roll-hardened 24S-RT sheet with

its 70,000 psi. tensile ultimate, 55,000 tensile yield, and 42,000 shear ultimate for the former's 62,000, 41,000 and 40,000 respectively.

So we scan the fast decreasing possibilities of weight saving on our 50,000-lb. airplane. Only

Table 1—Analysis of Metals in 4-Engined Airplane Structure

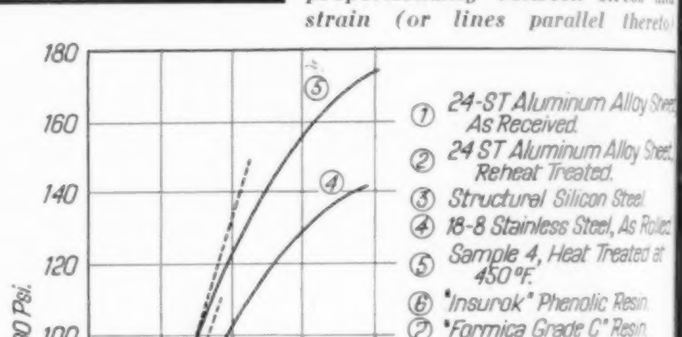
METAL	FORM	WING	FUSELAGE	TAIL SURFACES	LANDING GEAR	CONTROLS AND MISC.	TOTAL
Steel	Cr-Mo	300	200	20	1000	80	1,600
	Stainless	500	50	. .	. . .	50	600
Magnesium	Castings	. . .	. . .	. .	. . .	50	50
	Sheet	7000	2100	800	100	500	10,500
	Extrusions	150	100	50	25	175	500
Aluminum Alloy	Drawn parts	950	400	100	. . .	50	1,500
	Castings	. . .	. . .	. .	. . .	100	100
	Forgings	150	50	25	100	25	400
	Rivets	250	100	50	. . .	50	450
Others	All	20	20	20	40	100	200
				Grand total for structure			15,900

the extrusions and drawn or rolled sections remain to be investigated, and in Table 1 again we see that there are only 2000 lb. of them in the structure.

Will a substitution of magnesium alloy stringers for those of 24S-T aluminum alloy save weight? Some, perhaps, but not as much as the densities might indicate. We cannot use the hard-rolled sheet, Type Eh, for its strength (see Data Sheet in METAL PROGRESS, October 1940 Reference Issue, page 534), for it must be formed hot, and the cold-worked properties then revert to the Type Ea or annealed metal. A better comparison is of extrusions: 24S-T aluminum alloy extrusions in aircraft gages may be depended upon to develop considerably better than the manufacturer's minimum guarantee of 57,000 psi. ultimate tensile, 42,000 yield in tension, with a 12% elongation. Type "J" Dowmetal, a worthy magnesium alloy extrusion substitute, develops values of 43,000, 30,000 and 17% respectively. These values are so much lower than the aluminum that the answer is not found in changing to other light alloys now available.

Now let us see what "cold working" or "pre-stressing" our original 24S-T extrusions and drawn shapes will do. It has long been known, of course in a general way, that cold working increases the available strength of metals, and some years ago we at the Consolidated Aircraft Corp. attempted to discover whether practical shop procedures could be developed that would justify the operation. Laboratory tests were conducted, effects on the material studied, factory procedures very slightly changed, and today our Model 31 Flying Boat may be seen rising from San Diego Bay with wing loadings exceeded only by companion ships of later design, with wing, hull, and tail surfaces completely reinforced by pre-stretched stringers. The amazing fact is that no extra manufacturing equipment was

Fig. 1 — Stress-Strain Curves, at the Yield Point, of Several Materials for Aircraft Structures. Dotted lines are extensions of region having proportionality between stress and strain (or lines parallel thereto)



needed other than draw benches and straightening benches. With no extra production steps, the strength of the zee stringers on this boat has been increased in tension by approximately 28% at yield, and in compression (in plate stringer combinations) by nearly 6% at failure. The weight saved is considerable, as will be developed in the latter portion of this article.

It may be well, at the outset, to define the terminology. "Uni-directional cold work" is obtained by working the material in only one direction, as in stretcher straightening, pre-

stretching, or pre-compressing as a column. "Poly-directional cold work" is a result of deforming in two or more directions, as in upsetting, cold-rolling, or cold-forging.

The simplest form of uni-directional cold work is that obtained when a laboratory technician loads a tensile specimen beyond the elastic limit. Figure 1 shows the stress-strain curves for several common aircraft materials in the yield region. At point *a* on Curve 1 for 24S-T the proportional elastic limit has been reached and, beyond this point, Hooke's law of "stress proportional to strain" is no longer applicable. If the load were to be carried from *a* to point *b*, for instance, and released, the stress-strain curve would fall back on the line *bo'* and a permanent set of 0.002 in. per in. result. A second application of load to this same tensile coupon would cause the new curve to follow the *o'b* line again, reaching point *b* and then continuing on the conventional 24S-T curve. The re-test has a definite "knee" at *b*, higher than it originally was, and this is quite characteristic of cold-worked material. Cold working has resulted in increasing the "proportional elastic limit" (p.e.l.) from 49,000 psi. of the basic material to 55,000 psi. Likewise the whole stress-strain curve of pre-stretched material will be correspondingly translated to the right, and have an increased "yield point at 0.2% set", as at point *c* on Fig. 1.

A material can only be cold worked in proportion to its original ductility, in terms of the elongation at failure. At *c* we have used up approximately 0.9% of the normal 24S-T elongation of 17%. There still remains plenty to care for shop operations and energy storage qualities under service shocks.

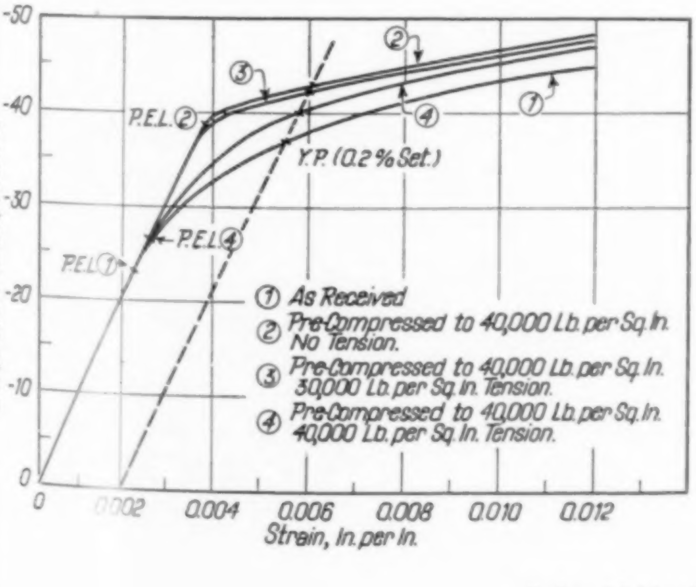


Fig. 2—Stress-Strain Curves in Compression of 2x0.083-In., 17S-T Seamless Tubing, as Received From the Mill, and After Certain Pre-Stressing Programs. Pre-compression raises the proportional elastic limit in compression (Holt and Hartmann)

Early Test Results

As early as 1937 some interesting contributions to our knowledge of pre-compressed columns of the aluminum alloy 17S-T were made by Messrs. Holt and Hartmann of the Aluminum Co. of America's research laboratories. Figure 2, from their work, shows that the p.e.l. of 17S-T aluminum alloy tubing, tested in compression as a short column, was increased from 23,000 as received from the mill to 39,000 psi., a gain of 70%, if the tube was pre-compressed 40,000 psi. under such conditions of support as prevented buckling or other column failure. Pre-compressed 2×0.083-in. tubing, used as columns of various lengths, developed crippling stress on very short samples as high as 55,000 psi.; in "short columns" with round ends it gained 33% in strength at a slenderness ratio $L \div \rho$ between 40 and 50; and in "long columns" with flat ends it gained 25% in strength at slenderness ratios between 80 and 100. These percentages represented improvements over the allowables in conservative design as practiced five years ago.

Still being of an investigative trend of mind, these researchers then applied 30,000 and 40,000 psi. tension stresses to the pre-compressed tubes, with results as shown in Fig. 2. Application of 40,000 psi. pre-compression to the 17S-T tube, followed by a 30,000 psi. pre-tension, gives us a considerable net gain shown in Curve 3. This effect and its reverse are very important, for each wing upper surface stringer that is designed for certain compressive stresses in flight (say + 5 g. or five times the force exerted by gravity in free fall) may be subjected to −3 g. on a hard landing, thereby applying 60% as much tension as the original compression.

Early in 1940 Messrs. Templin and Sturm of the same Alcoa research group presented a fine paper in the *Journal of the Aeronautical Sciences* on the stress-strain characteristics of several metals well beyond the yield point in both tension and compression. In Fig. 3 (page 38) are shown some of their cyclic stress-strain curves undertaken on aluminum specimens suitable for testing either in tension or compression. At left of this sketch are cyclic curves beginning with tension and

following the usual stress-strain curve to *a*, whereupon the load is released and the curve falls off parallel to the initial modulus line. It intersects the horizontal axis at a strain of approximately +0.002 in. which marks the amount of permanent set from the initial tension load. At point *b* the load is shifted to compression and the loading continued down to *c*. Compressive load is then released and the stress-strain curve comes back to the origin, again following a path parallel to the original modulus line. In this first cycle the compressive load *c* was so chosen, in relation to the tensile load *a*, that the stress-strain curve returned to the origin *O*.

The tension cycle is now repeated, this time to the higher load *d*, then reversed into the compression region to point *e* and the load released.

Several interesting features exist on this family of curves: First, the "cold work knee", caused by the initial "as-received" cold work, appears only on the original tensile cycle at *f*. Second, the loops close within experimental accuracy. Likewise, as shown by the curves on the right side of Fig. 3, when the stress cycle is carried out in the reverse direction the loops also close, and the modulus (the slope of the straight portions) remains constant in both sets of curves and is the same in tension as in compression.

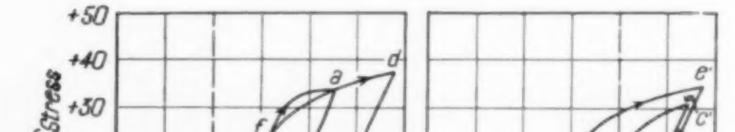


Fig. 3 — Cyclic Tensile and Compressive Overloadings of 17S-T Rolled Rod Eliminate Original Proportional Elastic Limit f or f', but do Not Change the Slope of the Modulus in Either Tension or Compression (Templin and Sturm)

Figure 4 summarizes the gains obtained by Messrs. Templin and Sturm on the strong aluminum alloys after a pre-stretching. To the left in solid lines is shown the per cent change in yield strengths of 17S-T extruded rod against per cent pre-stretch (in terms of permanent set) when the stretching operation was performed several days after heat treatment. A slight loss (decrease of about 4% in the yield stress in compression) occurs at low pre-stretch, but this is overcome when the pre-stretch reaches 2½%. Aging has a pronounced effect; pre-stretching within 1 hr. after heat treatment is only a fraction as effective as though the work is delayed for several days' aging.

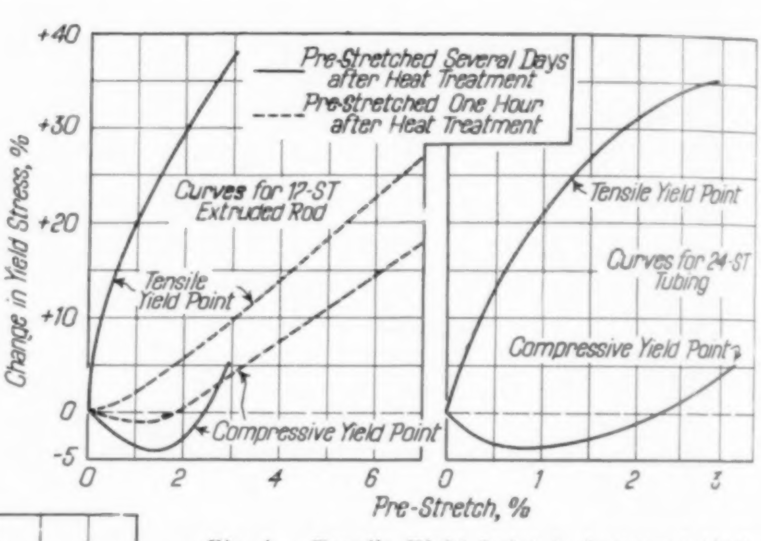


Fig. 4 — Tensile Yield Point Is Increased About 35% and Compressive Yield Point Unchanged by 2½% Pre-Stretching of Heat Treated and Aged 17S-T and 24S-T (Templin and Sturm)

The curves for 24S-T tubing are comparable to the ones for 17S-T extruded rod, stretched after aging. Tests on the 24S-T tubing were made after various intervals between heat treatment and pre-stretching, but all faired into the "aged curve", indicating that aging occurs rapidly in 24S-T.

Practical Applications Already Made

Work such as this, as well as check results at our own laboratory, has already resulted in a worth-while saving in main members, despite the conventional practice of correcting structural test results down to the minimum allowable yield point guaranteed by the material manufacturer. If this minimum guarantee could be raised or the material could be cold worked by the aircraft manufacturer to properties above those in the "as-received" condition, this

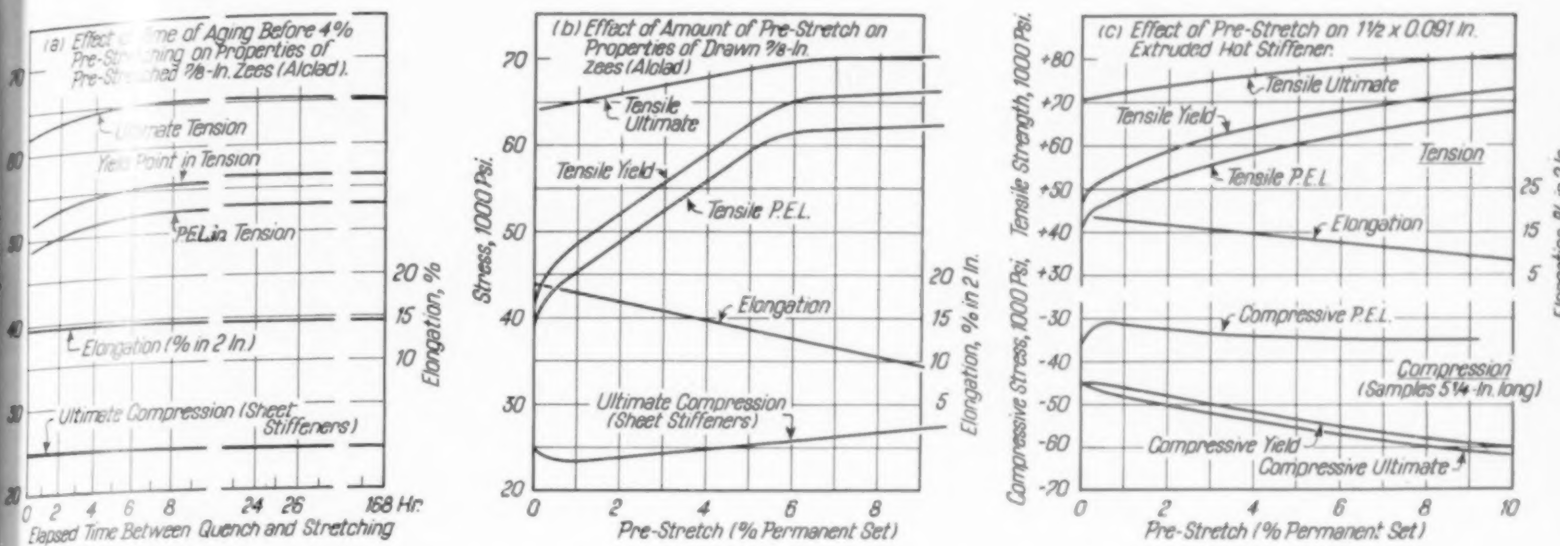


Fig. 5 — Tests on Pre-Stretched 24S-T Aluminum Alloy. Left and center diagrams are for 7/8-in. drawn "zee" stiffeners made of alclad sheet. Right diagram is for extruded "hat" stiffeners

correction would not be as large as it is now.

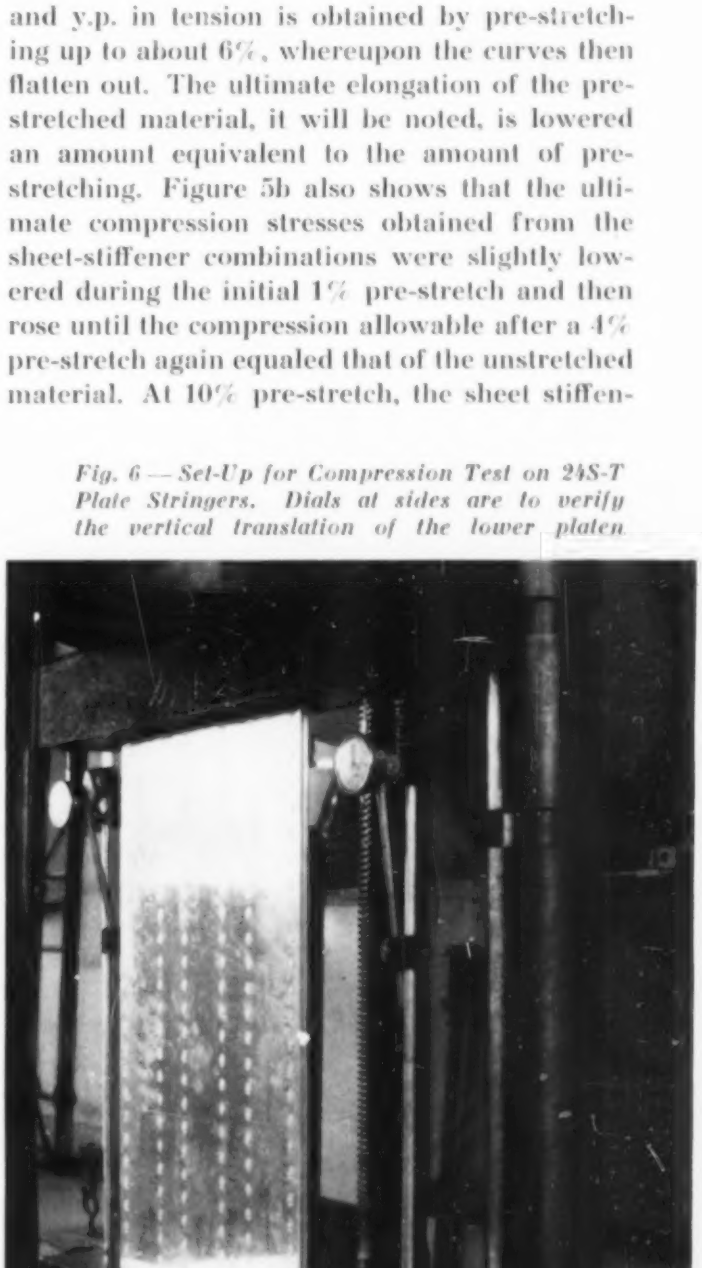
Consolidated Aircraft Corp. has found that a definite strength-weight gain can be made if controlled and cold-worked material is used in major structural assemblies. Its present practice in manufacturing stiffeners intended for such structures is to draw the various shapes from strip stock in the annealed or soft condition. They are then heat treated and aged and then stretched enough to leave approximately 3½% permanent set.

In the last four years the Consolidated Aircraft research department has studied, among other things, the effect of the time intervening between quenching and stretching. Figure 5a was obtained from 7/8-in. deep-drawn zees pre-stretched 4.0%, plotted as the summation of the tensile properties taken from 16 stress-strain charts and from a like number of sheet-stiffener compression tests.

Tensile properties of the material prestretched after aging 24 hr. were higher than similar properties obtained immediately after heat treatment. These increases amounted to 8% for the p.e.l., 8½% at yield, and 4% at ultimate. However, if the 7/8-in. drawn 24S-T zees were held only 6 hr. and then pre-stretched, little further gain could be obtained by a longer delay. This finding is in accord with tests by Templin and Sturm. Elapsed time had negligible effect on the other properties shown, or the ultimate compressive strength of sheet-stiffener combinations.

The effect of increasing amounts of prestressing in tension on the same material is shown in Fig. 5b. A rapid increase in the p.e.l. and y.p. in tension is obtained by pre-stretching up to about 6%, whereupon the curves then flatten out. The ultimate elongation of the prestretched material, it will be noted, is lowered an amount equivalent to the amount of prestretching. Figure 5b also shows that the ultimate compression stresses obtained from the sheet-stiffener combinations were slightly lowered during the initial 1% pre-stretch and then rose until the compression allowable after a 4% pre-stretch again equaled that of the unstretched material. At 10% pre-stretch, the sheet stiffen-

Fig. 6 — Set-Up for Compression Test on 24S-T Plate Stringers. Dials at sides are to verify the vertical translation of the lower platen



ers gained 17% in ultimate compression stress over that of the untreated combinations.

Sheet-stiffener units were tested by compressing the flat-ended panels between platens of a hydraulic testing machine as shown in Fig. 6. The panel ends had previously been ground flat and parallel.

Extruded shapes may also be pre-stretched with appreciable betterment. For instance, a 1½-in. deep "hat stiffener" of 0.091-in. thick 24S-T extrusion gave the results shown in Fig. 5c when stretched various amounts. It will be noted that *extruded* stiffener material pre-stretched 3½% will develop a yield point in tension which is about 19% above the value that may be expected from the same extruded material in the "as-received" condition. (Ultimate tensile strengths are approximately the same.) The compressive yield point is where 0.002 in. per in. set occurred. A study of another hat section of thinner wall (0.078 in. gage), when pre-stretched 3½%, shows that the 24S-T extruded material in tension is about 16% stronger at ultimate and 14% stronger at yield than the drawn 24S-T alclad.

Use of 5¼-in. long double-hat columns, with their low slenderness ratios, did much to simplify and cheapen the determination of the stiffener crippling stresses, formerly studied by using complete sheet-stiffener combinations. Much testing time in man-hours was saved with these specimens because it was much more simple to insure uniform distribution of the load over the bearing area.

In the tests every effort has been made to control the many variables. Material for each type of drawn stiffener tested was sheared from the same sheet or strip stock or from the same extrusion, thereby controlling the basic material. Stiffeners intended for a specific test were solution heat treated in one group in the nitrate bath. The ends of each compression specimen were carefully ground flat and parallel. The most accurate practical methods were used in determining compressive strains by either Huggenberger 1000:1 gages, or the more practical and accurate "celstrain" wire resistance gages, or both. A typical set-up to determine the uniformity of bearing on a double-hat specimen is shown in Fig. 7.

Consolidated Aircraft Corp. has also attempted to develop a practical method whereby the pre-compression of stiffeners might be applied to production, a far more difficult job than pre-stretching, since the column instability and tendency to local buckling of light aircraft sections has to be resisted during the operation.

Two methods were attempted; first, in individual 24-in. lengths restrained in hardwood forms cut to the shape of the hat stiffener and bolted together; and second, in 120-in. lengths also restrained by wooden forms. In the first test jig the compressive load was applied in a 200,000-lb. hydraulic testing machine, and a hydraulic jack in the second.

To check on the relative effect of pre-stretching and pre-compression, short lengths of 24S-T alclad drawn hat sections, pre-compressed various amounts, were used as stiffeners at 5-in. centers on alclad sheet as received, and the assemblies tested in compression. The ultimate strength in compression increased directly with the amount of permanent set imposed by the pre-compression, from 37,500 psi. when the assembly was built of material as received, to 43,500 psi. when it had been pre-compressed to a 2.1% permanent set. This is a gain of 16%.

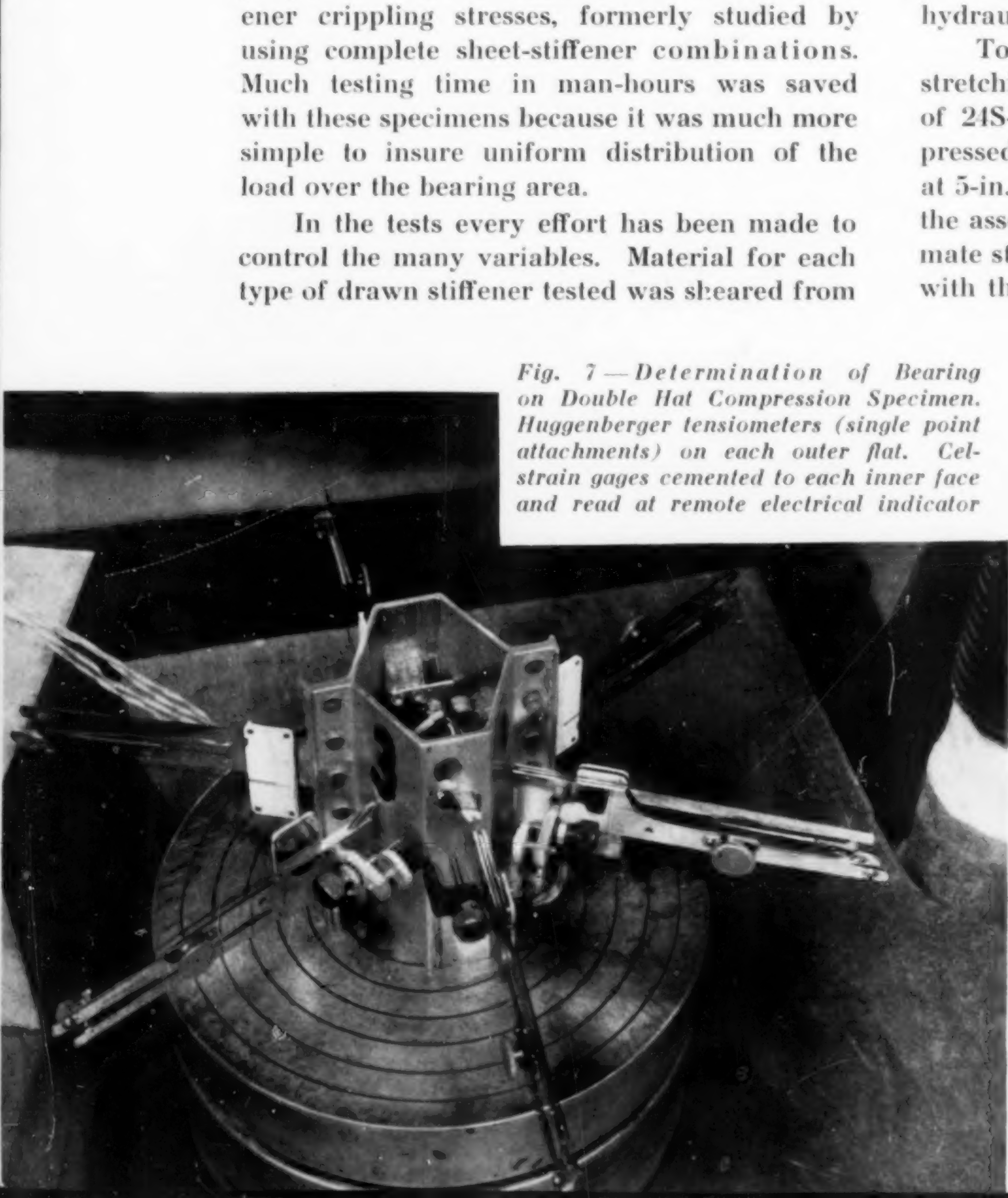


Fig. 7 — Determination of Bearing on Double Hat Compression Specimen. Huggenberger tensiometers (single point attachments) on each outer flat. Celstrain gages cemented to each inner face and read at remote electrical indicator

Extruded hat sections, tested in both tension and compression, gave curves similar to those in Fig. 3, and showed a slight difference in modulus, 10,250,000 psi. in tension and 11,500,000 in compression. This is no more, in the author's testing experience, than the experimental scatter to be expected when testing aluminum alloys. If a 20-ft. long extrusion of 24S-T is heat treated under controlled conditions for 45

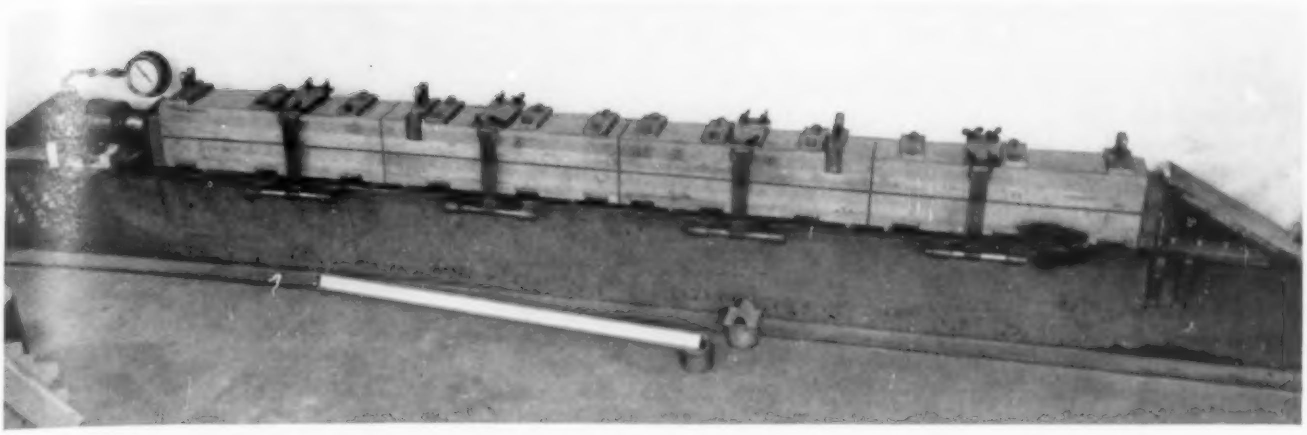


Fig. 8 — Fixture for Pre-Compressing Long Extrusions. Each supporting block is movable end-wise between hold-down and supporting rollers

min., the section straightened by 1½% stretch, and 10 tensile samples picked at random from its length, the individual specimens may vary by as much as ± 4% in the yield point and proportional elastic limit. With this variation present in a *controlled* situation, more design or shop accuracy than this experimental spread warrants should not be expected.

There are also variations in the material to reckon with, and unfortunately 24S-T is not so uniform in its response to treatments as might be anticipated. Table 2 shows tests on two extrusions of the same section, received in different shipments. The tensile values as received were so different that an "off" composition was suspected, but the analyses checked reasonably well. Past experience indicated that such extrusions might already have been pre-stretched anywhere from 0.5 to 1.5% in straightening, but even this would not account for the spread of 12,000 psi. in the *ultimate* strength. The conventional heat treatment was tried for 45 min. without much influence. A second 45-min. heat treatment still resulted in a spread of 10,000 psi. Finally, in desperation, the extrusions were soaked in the 930° F. salt bath for over 9 hr., with the desired equalizing results. A subsequent pre-stretch at 60,000 psi. after the 45-min. heat treatment boosted each extrusion to slightly above its original "as-received" ultimate tension values, but with marked increase in the yield point and proportional elastic limit over the original values.

Thus, our sleuthing has uncovered two interesting features of 24S-T aluminum alloy, cold worked; first, that considerably more than the normal 45 min. of heat treatment may be necessary to remove the effect of the "poly-directional" cold working of extrusions during manufacture; and second, the capacity of various shipments or batches of extrusions to increase in properties from a common level by pre-stressing may differ considerably.

Recently we have attempted to make a more

Table 2—Comparisons of Two 1½x3¾x0.078-In. Extruded 24S-T Hats

	Specified	Extrusion A			Extrusion B		
Copper	4.4	3.96%			4.00%		
Iron	..	0.22			0.31		
Manganese	0.5	0.73			0.69		
Magnesium	1.5	1.19			1.05		
Silicon	..	0.12			0.10		
Aluminum	93.60	93.78			93.85		
		Ultimate	Yield	P.E.L.	Ultimate	Yield	P.E.L.
Minimum Alcoa values		57,000	42,000	....	57,000	42,000	....
As received		66,000	45,000	....	78,000	55,000	....
Heated 45 min. at 930° F.		65,100	42,000	34,000	77,100	49,600	43,000
Reheated 45 min. more at 930° F.		65,250	42,100	31,500	74,700	47,500	38,500
Third heating (9¾ hr. total)		64,000	41,500	33,000	66,100	41,600	26,700
Pre-stretched by 60,000 psi.★		68,800	64,500	46,500	78,200	64,500	63,000

★After first 45-min. anneal

Table 3—Strength of Pre-Compressed Hats

Condition	Location	Ultimate	Yield	P.E.L.*	$E \times (10^{-6})$
1½x4¼x0.091 Rolled 24S-T Alclad, Heat Treated and Aged					
Heat treated and aged		−51,500	−44,700	−34,000	9.0
Pre-compressed 60,000 psi.	Center 1	−51,500	−51,000	−46,500	10.0
	Center 2	−52,000	−51,800	−48,500	9.5
	Center 3	−51,600	−51,000	−46,000	9.6
	Center 4	−51,700	−51,400	−46,000	9.5
	Average	−51,450	−51,300	−46,750	9.6
1½x3¾x0.078 Extruded 24S-T					
As received	....	+75,100	+55,200	+50,000	10.6
Pre-compressed 60,000 psi.	Center 1	+74,100	+49,200	+41,000	10.0
	Center 2	+74,000	+51,200	+43,000	10.0
	Center 4	+75,450	+50,000	+40,500	9.7
	Average	+74,520	+50,080	+41,500	9.9
As received	....	−53,650	−49,400	−39,000	11.6
Pre-compressed 60,000 psi.	Center 2	−56,100	−56,000	−55,000	10.6
	S. End 2	−55,800	−55,700	−53,500	10.6
	N. End 1	−58,000	−58,000	−54,000	11.3
	S. End 1	−55,450	−55,400	−53,000	10.9
	Average	−56,340	−56,280	−53,880	10.8

*P.E.L. is Proportional Elastic Limit; plus sign means stress in tension, minus sign means stress in compression.

practical pre-compression fixture for stressing hat stiffeners in long lengths. Figure 8 shows one such pre-compression jig. Between two end brackets on a very sturdy I-beam was placed the 120-in. long hat specimen, well protected against lateral buckling and local failure by greased wooden blocks, and loaded with a calibrated hydraulic ram. Space was left between each pair of wood segments and at each outer end to provide for the shortening of the specimen during pre-compression. The wood blocks could move parallel to the applied load since they were supported and held down by steel rollers.

Some of the results are shown in Table 3. Pre-compression to 60,000 psi. caused no change in the compression ultimate of rolled 24S-T alclad hats when measured on 5-in. long double-hat columns cut and fabricated therefrom. The yield point was raised 15% and the proportional elastic limit 20%. Note, too, how uniform are the stresses obtained from samples taken at the centers of each of the 31-in. wood guides, where the friction loss would be expected to cause the greatest reduction in pre-compression effect. This uniformity was not accidental, however, since many preliminary tests were made to discover how to reduce the friction to a minimum and to find the torque to be applied to each hold-down bolt.

Pre-compression increases the average compressive yield point in 24S-T extrusions (Table 3, lower portion) by 14%, and the proportional elastic limit by 38%. But on this specimen the reduction of tensile properties by pre-compression is evidenced in the 9% drop in yield point and 20% in proportional elastic limit in tension. Some evidence of local wrinkling of the hat section occurred at the ends of each wooden guide, indicating that we would have a more perfect specimen after a 55,000-psi. pre-compression, but with less gain in compression properties and incidentally less tension loss.

Practical Application to Aircraft

Now what can be done in applying the findings of this research to our pressing production problems? That the pre-stretching of 24S-T and 24S-T alclad drawn and rolled sections is practical is attested by the fact that Consolidated Aircraft Corp. is using 3½% pre-stretch on stiffeners and drawn spar flange angles on over half of the current production contracts, and will probably increase its use as new aircraft models replace those designed for extrusions.

The increase of the pre-stretch above 3½% permanent set does not seem to be justified, for three reasons:

1. The major increase in structural properties occurs early in the plastic range.
2. The higher the pre-stretch, the lower will be the residual elongation available to accommodate possible stress concentrations and dynamic loads.
3. The higher the pre-stretch, the more material rejected, since slight surface irregularities and edge saw cuts or shear marks form stress raisers and cause premature tension failure during the pre-stretching operation.

Pre-compression of aircraft structural members is not yet practical, in the author's estimation. More possibilities are offered in the rolling to shape of 24S strip stock in the heat treated and pre-stretched condition, thereby allowing for the necessary spring-back and eliminating

(Continued on page 88)

CRITICAL POINTS

by the editor

DISCUSSING with JOSEPH DANIELS, professor of mining engineering and metallurgy at the University of Washington, the chances that a large metallurgical industry could be built on the West Coast — especially in his own Northwest. (This was before the recent offer by Columbia Steel Co., Colorado Fuel & Iron Corp., and Bethlehem Steel Co. to expand their furnace and mill capacities at Los Angeles, Pueblo, Provo, and San Francisco by a million and a half tons of steel ingots annually — an expansion of 75% — to help take care of the Coast's shipbuilding and other defense efforts. In fact, the two events had no relationship.) Pacific coast openhearths depend largely on scrap, melting as much as 3 tons per ton of pig iron in comparison to the 1 to 1 ratio for the rest of the country. At present the whole region is drained of scrap, so any large steel industry in the Pacific Northwest, at least, would have to base on pig iron, locally smelted if possible. . . . . DANIELS called inaccurate the oft-repeated statement that the region has no coking coal; there is plenty of coking coal but it is higher in ash than eastern coals — reducible by washing at the expense of yield, making the problem one of economics, to balance against cost of fluxing the ash in the blast furnace. However, fuel *is* available; usable coke has been and can be made. From 1880 to 1937 beehive and byproduct ovens supplied this state with coke for every use except electrometallurgical. . . . . Iron ore deposits are numerous but probably small, not suitable to a big operation; the ore could be brought from large mines in Wyoming or Utah over existing railroads now operating below capacity — or preferably shipped from Chile where most of our imported ore now comes from. . . . The existence of large amounts of hydro-electric power drastically alters the metallurgical possibilities. A large aluminum plant is even now operating on Bonneville power. Why not use another block of it for magnesium, with Puget Sound as the "mine"? Chromite and tungsten from the Sierras, the orient, and the countries to the south of us could pause here long enough to be smelted into ferro. Raw materials for ferrosilicon are available anywhere there is power. Professor DANIELS also suggests a quality iron industry based on Swedish electro-smelting practices, using local ores or magnetite from Utah, coke from Washington coals, and power from the rivers. (Wood distillation has never been practiced out there, where lumbering wastes are burned to get rid of them. Why, I don't know — probably $ and ¢. Perhaps it is dangerous to draw a parallel, but for every $4.10 ton of coke made in America in 1939 the ovens sold $3.25 worth of byproducts.)

An Electro-Metallurgical Industry for the Northwest

INSPECTED California Institute of Technology at Pasadena with DONALD CLARK, assistant professor of mechanical engineering, and much impressed with the various aspects of sound technical education there observed. Among these are small sections in each class; high proportion of graduate students to undergraduates; comfortable housing for students; buildings and laboratories of recent construction in a beautiful setting, architecturally harmonious; the coexistence of faculties in humanities, pure science and technology; and active and successful research work by the teaching staff. . . . . Examples of the latter are shops large enough to construct portions of the great 200-in. telescope for Mt. Palomar and the three-year job of grinding the principal reflectors, the aeronautical laboratory which is more than self-supporting from its wind tunnel work, and the hydraulic laboratory which perfected designs of pumps for the aqueduct from Colorado River representing savings of $1,400,000 in construction costs and $120,000 in annual power bills. CLARK, who is in charge

High Grade Teaching & Research

of physical metallurgy at the Institute, has completed a long research into high velocity impact sponsored by numerous metal producing and using firms scattered over the United States; in his equipment the forces absorbed during impact and the instantaneous length changes are measured by changes in electrical resistance in coils attached to the specimen and recorded on a cathode-ray oscillograph. These experiments show that steels do *not* lose practically all their resistance at speeds of 200 ft. per sec., a result contrary to some earlier experiments at Watertown Arsenal with equipment of quite different design.....Another of his interesting special devices records photographically the thermal transformations and the corresponding dilation of metal specimens during heating and cooling cycles at any desired rate; the furnace and photographic controls are entirely automatic — just set the apparatus going and 24 hr. later come back and develop the film. Painless research, what?

Driven by Telfer Norman, over fine auto roads and utterly indescribable mountains, through relics of such historic Colorado towns as Idaho Springs, Georgetown, Silver Plume, Dillon and Kokomo, the once-rich silver mining region, over Loveland Pass and its snow squalls to Climax where the molybdenum comes from. Shades of the pioneering Leadville miners, what a mining camp! Atop the Continental divide, steam heated and electrified with such refinements as an automatic solarium, where workmen step from shower to a moving platform carrying them slowly past a battery of ultra-violet lights.....Arrive, oh ye welcome visitor, before lunch time at the mess hall, but make not the social error of calling spuds "potatoes". Lunches are put up for those who must carry them at an overloaded sideboard, the only limitation apparently being the capacity of the commodious paper bag. But to things more metallurgical —

Mining Camp de Luxe

Climax Molybdenum Co.'s ore deposit, which had been located time and again before the turn of the century but never worked because the mineral was either unknown or unwanted, is a huge vertical cylinder of fractured granite about half a mile in diameter with a conical core of lean ground. The Phillipson tunnel, named after the company's late president, penetrates the side of Mount Bartlett and serves as the main haulage way, above which the ore is caved down, 35 years' supply at the present mining rate of 13,000 tons daily. Below this level, 25 years' more ore (0.4 to 0.7% MoS_2) has been proved by diamond drills.....As explained by E. J. Duggan, mill superintendent, molybdenite (MoS_2) is one of the easiest minerals to float, a particle of rock rising in the froth of a flotation cell if only the tiniest speck of sulphide is laid bare. For that reason a concentration of 25 to 1 can be made on ore crushed no finer than through a 28-mesh screen, and only the float (now containing 12% MoS_2) need be finely ground.....Final concentration to 90% MoS_2 is done in three successive stages of grinding and flotation, the feed going to the flotation cells being progressively finer and richer. Since the ore contains about four times as much pyrite (FeS_2) as molybdenite — and 0.02% copper, just enough to be a nuisance — these other sulphides must be "depressed" while the values are floating; a little cyanide added to the oily pulp does the trick. The final black froth is as thick as whipped cream; water is sucked out of it and then it goes through a Lowden drier (a glorified hot plate), and is bagged for shipment.....About 6 lb. of molybdenum is recovered from each ton of ore, making the yearly production of Climax at the present rate some 27½ million pounds (14,000 tons) of metal. Since half of the concentrate was exported prior to the blockade, American utilization of this entire tonnage requires extensive additions to the roasters and electric furnaces for converting the sulphide into ferro (now done at Langeloth, Pa.).

27,500,000 Pounds of Molybdenum per Year

Another distinction held by Climax is the possession of a metallurgist to check receipts of metals and study their performance in mine and mill — a useful employee, judging from the fact that one third of all incoming supplies are metallic. Harold Blackett described his researches on grinding materials. Forged and heat treated balls, 3 in. diameter, are bought by the car load. The present standard is made of 0.80% C, 0.25% Mo, 0.70% Mn steel, water quenched to a martensitic shell about 660 Brinell hard; its hardenability is such that in this size the center hardness is about 450. Some 50 different commercial or experimental analyses and treatments have been tested, not by using up 100 tons of each in a 6-months' campaign, but

Better Steel Balls for Grinding Ore

as follows: Two dozen new balls of each lot are deeply marked by drilling or grooving in a simple but distinctive pattern, as well as a similar number of new balls of the standard, and these marked balls are then added to the load in one of the regular ball mills. At the end of a week's run the mill is shut down, dumped, the marked balls recovered and segregated, and their merit numbers determined by weight loss. Tentative results secured to date include these: "Standard" balls from approved vendors vary no more than 5%, shipment to shipment, and less than that, ball to ball; some commercial grinding balls tested have shown only half the durability of the "standard"; the durability when grinding this quartzose ore is not directly related to the hardness of the grinding materials; the lowest cost is probably secured from deep hardened balls but little softer at center than at the surface.

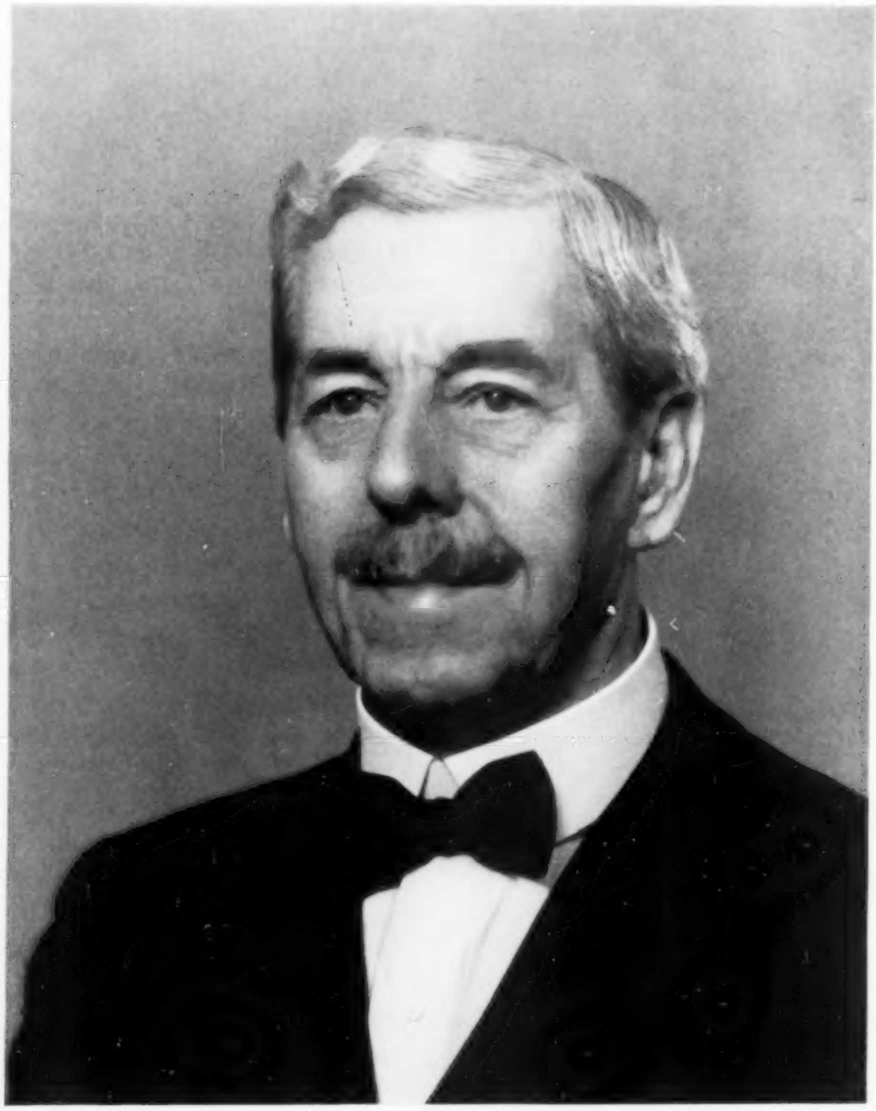
One Railroad Where "Nothing Runs With a Crack"

Out to Burnham shops, near Denver, to visit Ray McBrian, engineer of tests for Denver & Rio Grande Western Railroad ("The Scenic Railroad of the World" — and that's no advertising man's blurb, either!). Five years or so ago he sold the management on the need for magnaflux inspection of some 30 vital locomotive parts on every monthly overhaul on every engine. The iron-clad rule was laid down: "Nothing runs with a crack." In the first six months 19 cracked siderods were sent in to the laboratory for study; in the second year 59. This was serious enough to warrant a complete research on transparent models under polarized light, and to change the design to eliminate stress concentrations. The next year 28 siderods were removed (and the scratches filed out or the piece scrapped); next year 12, and this year to date only four rods have been received for study. Similar examination and improvement of other engine forgings have reduced the number of engine failures on the road to where it is now one of the lowest for all Class I railroads. (Small wonder the test department and its laboratory is moving into a much larger building!) E. A. West, general manager of the railway, strongly believes that all dead motive power and car equipment resurrected for service in this emergency be closely examined for incipient fatigue cracks, else breakdowns on the road will cause more delay and trouble than good. . . . McBrian has also given much attention to failures in crown sheets and staybolts, which have become epidemic in all modern high pressure locomotives. Momentary temperature and pressure variations cause "breathing" movements, overstressing the fire side of the crown sheets, always slightly decarburized and therefore having a lower fatigue resistance. For this reason cracking starts from sharp rivet-hole corners. A further complication is the aging of the low carbon steel; originally the yield at 0.2% set is 60% of the ultimate, but after use it rises to 80% and so reduces the amount of ductile action the sheet can stand during a sudden overloading emergency. Rimming steel is the worst offender in this respect, and is prohibited by D. & R. G. specifications. Pending the discovery of a non-aging steel, McBrian now specifies a 0.50% Mo steel of fire-box quality; the molybdenum — although of small solubility in ferrite — enhances the fatigue resistance of the decarburized skin so that it cracks much less readily. Its strength at 1585° F. is also 13,400 psi., as compared to 5600 psi. for plain carbon fire-box steel at the same operating temperature. . . . . P.S. Here's an addition and a correction for the Metals Handbook, page 461, on "Alloy Wrought Iron". Wrought iron staybolts containing 0.50% molybdenum made by Penn Iron and Steel Co., when tested at 1000° F., have a yield at 0.2% set of 20,800 psi. and an ultimate strength of 33,800. Ordinary wrought iron under the same conditions has 12,200 psi. yield at 0.2% set and 18,700 ultimate.

Release of Key Employees From the National Army

Referring to the item printed in this department in April, headed "Deferment of Draftees Necessary for Production", it may now be stated that an enlisted man (not a reserve officer or a Naval rating) who was a key employee in necessary industry may now be discharged from active service on condition he resumes his civilian employment immediately. The application for discharge must be initiated and executed under oath by the responsible head of the employing firm. Full information about correct procedure is contained in a statement of War Department policy regarding discharge of selectees from active service, issued by the Under-Secretary of War on May 23, 1941.

SAUVEUR MEDALIST



Walter T. Cocker

Adolph Wilhelm Machlet

Chosen by the Committee of Past Presidents, American Society for Metals, to receive the Albert Sauveur Achievement Award at the 1940 Convention, in recognition of his "many inventions of processes and apparati which have very markedly accelerated progress and development in the metallurgical field, and have been of public benefit because of their increased safety."

ADOLPH W. MACHLET

SEVENTY YEARS AGO, GEORGE W. MACHLET, a manufacturer of jeweler's supplies, left Germany to emigrate to Newark, New Jersey, then the center of the jewelry industry in America. With him he brought three sons. He settled on an acre of ground in the outskirts of Elizabeth, and in due time built a home, two-storied and high-ceilinged, comfortable and roomy. Eventually his sons entered his business, but his second son ADOLPH, the subject of this biographical appreciation, was more interested in the birds and bugs and flowers in the orchards around about. This first love still burns — the entrance to his office looks more like a conservatory than an office corridor, and ADOLPH WILHELM MACHLET, now patriarch of the American Gas Furnace Co., makes constant allusions to botanical subjects and ever seeks relationships between man-made mechanisms and God-made organisms.

He now is the embodiment of the homely business virtue of making things as honestly, as good and as sturdily as he can. "Plant well, and let the oak tree grow," is his motto. Good goods are bound to make a little money. His company is a literal example of Emerson's mouse-trap maker in the woods, for the factory built in the side yard of a country home now faces the super-highway carrying New York traffic to the South.

The whole thing springs from some trouble the elder MACHLET (together with other manufacturers in the jewelry trade of the day) were having with variable gas flames. Bunsen burners were always used, and as every chemistry student knows, the air for combustion is aspirated into the fixture by the passage of the gas. In those days the city gas was led to the work benches in small lead pipes, easily dented if accidentally struck, whereupon the gas flow would be cut and the burner would not deliver the heat. MACHLET, Sr., decided to reverse the process — bring air to the burner at moderate but *constant* pressure and let the air draw in its proper amount of gas.

The idea was a good one, as proved by the fact that this principle now underlies practically all industrial gas heating devices, but it took ten to 15 years to convince any of the big jewelry firms that it would make a better melting flame than coke or charcoal-fired furnaces. Meanwhile the family business, tools for jewelers, paid for experiments and perfection of equipment. At this stage GEORGE W. MACHLET, jointly with Major EDWARD P. REICHHELM, founded the American Gas Furnace Co. Mr. MACHLET recalls that "Everything had to be developed new. The Roots blowers gave an air blast too pulsating; we had to manufacture our own blower. We determined the best lines for the Venturi gas-air mixer by blowing air through tobacco smoke. A zero-pressure gas regulator had to be devised. There were not even gas lines out as far as our house for years. We three sons were close to our father, and we would experiment, consider and discuss the results for long evenings, and then plan others." The first milestone was passed when the new gas burners got Uncle Sam's approval, and the New York Assay Office installed them for melting bullion.

It was only natural to extend the gas heat from Machlet burners to the hardening of jewel-

er's tools in the family business. However, most smiths thought their forges were good enough. "It costs too much" was the common objection to a muffle furnace. A minor triumph was achieved when FRED J. MILLER, editor of *American Machinist*, printed an article about some cutters hardened in a gas-fired furnace, and pronounced them excellent. Gradually a good business in commercial heat treating was acquired, and in 1907 the American Metal Treatment Co. was organized and installed in an empty building a quarter of a mile away. J. W. JOHNSON, president of Johnson and Johnson (the New Brunswick manufacturers of surgical supplies, but then the owner of "Neverslip calks", and good customers) was the financial angel, and great was the temerity of anyone to venture capital in new businesses during the financial panic of 1907.

Young ADOLPH MACHLET had long since devoted all his time to the furnace business. The heat treating end was especially fascinating. Carbonaceous gas seemed to be the almost vital organic link connecting all the mechanical actions he was observing. He could dimly sense enormous hidden possibilities. It was clear that *gas* was the essential medium for casehardening, even though the steel parts were packed in bone and charcoal. Why not do it with gas alone?

At about this time (1906) several good furnace customers were having carburizing troubles, and parts were shipped to Elizabeth for treatment. Some were pack hardened in the conventional way; others, to test the gas carburizing idea, were heated in a container with city gas only. It worked so well that process patents were obtained in 1907. However, it was accepted by industry very slowly. The practical results were erratic. Even in Elizabeth, the process suddenly became inoperative for a mysterious reason, eventually found to be a new gas house that didn't scrub the sulphur compounds out of the gas delivered. (Likewise high sulphur screw stock would not caseharden.) This was a real handicap, although sulphur in the gas was removed by bubbling it through chloroform. This brought in the possibility of *adding* things to city gas, especially its dilution with inert materials to prevent sooting in the container, the addition of ammonia — the basis of the modern "Ni-carb" process — both processes patented in 1908, and the use of methane, butane and other hydrocarbon gases in place of city or producer gas.

Nitriding was also discovered by the Sauveur medalist at about the same time. When ammonia was part of the gas mixtures the parts came out too hard to machine; however, the method was abandoned by Pratt & Whitney, where it was tried commercially, because necessary parts could not be softened by annealing. Another handicap was that ammonia cost 25¢ a lb. Nevertheless, the basic nitriding process patent, applied for in 1908, was issued in 1913, and disclosed the principles that have never been changed. On account of the white, rust resisting surface of the nitrided parts, and to enhance the secrecy then thought so essential for metallurgical improvements, the articles were said to have a "hard nickel plate".

Unfortunately the attorney who wrote the patent specifications failed to include "alloy steel" in his category of items hardenable with ammonia (nitrogen) without quenching. Here an American inventor was a generation ahead of his time; little attention was given to the nitriding process for 15 years when it was imported from abroad, its use attached to a complex alloy steel. To the discredit of the ⚙, its 1929 Nitriding Symposium made only one six-line mention of ADOLPH MACHLET, the originator, while it recognized the men who later adapted it to alloy steel — ADOLPH FRY, the German, and PIERRE AUBERT, the Frenchman — as Honorary Vice-Chairmen.

This account pays more attention to the tribulations of the early days than the business successes of the later ones, but in all this time a continual stream of patents was issued on gas burners and control equipment, heating furnaces, and heat treating processes. These prove the versatility of the man, ADOLPH WILHELM MACHLET, and would as a group warrant the honors that have now been bestowed on him, over and above those two fundamental discoveries of gas carburizing and of nitride hardening. Still vigorously investigating the relationship between carbonaceous gases, nitrogen, metal, carbides and oxides, MACHLET's present experimentation runs toward the direct reduction of iron ore — a matter that has fascinated other keen minds. With characteristic originality he looks beyond the mere recovery of high grade metal from pure ore, or the recovery of metal alloys from mixed metallic oxides, to the possibility of alloys of iron and nitrogen, excessively hard from surface to center, produced from iron sponge properly reduced and then nitrided before agglomeration. ⚙

"QUICK, WATSON, THE MICRO"

what broke this shaft?

By R. M. Brick
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DETECTIVES of all sorts, police as well as metallurgical, are almost always called upon to ferret out the cause of some single, surprising happening, contrary to the laws of legislatures or of mechanics. Such crimes against society and against nature doubtless follow a pattern; each has broad similarity to others on record; yet each has a novelty (sometimes macabre) that makes it interesting even to the readers of such stories as these.

Contrary to the instances of the above type, briefly described in this magazine in March and in May, the metallurgical detective now turns his attention to recurring troubles in

V. The Epidemic of Broken Shafts

Rods, 1¾ in. diameter of S.A.E. 3140 steel (1.25% Ni, 0.60% Cr, 0.40% C), heat treated to a Brinell hardness of 240, should have sufficient strength for a high factor of safety when employed as shafts of rotating generator equipment. Yet at periodic and fairly frequent intervals, fractures of this material come around to the laboratory implicitly tagged "Why?" The failures were always of the fatigue type, showing wave markings where a crack had been slowly propagated across most of the section, then a final area was of normal failure by tension and bending.

In many of these cases the metal and design were both fully acceptable, but a lack of dynamic balance probably resulted in excessive vibration with correspondingly high fatigue stresses. Design does not in general seem to be faulty; at the point where many failures occur, there is a change in section from 2 in. to 1½ in., but the potential notch is eliminated by a generous radius, a fillet of ¼ in., rounding out the bottom. A keyway at the end also has rounded off inside corners, and thread cuts in this section are provided with rounded bases. The machined surfaces have not been polished, but in general show good finishes with no obvious deep tool cuts or similar imperfections that might start a crack.

In investigating these failures, a plane parallel to the axis of the rod was always polished, examined at 100 diameters magnification, and the number of inclusions in various size ranges counted. This "dirtiness" rating is decidedly variable; some of the older steels, rods in service 8 to 10 years, show numerous fairly large inclusions, 0.0075 to 0.0125 in. long, and internal cracks in their vicinity suggest they may have initiated the failure. In most cases, however, inclusions do not appear to be primarily responsible.

Etched microstructures have been quite variable for supposedly uniformly heat treated steel; grain sizes from very coarse, No. 1, to very fine, No. 8, have been found. Sometimes the micro shows pearlite with a ferrite network outlining the austenitic grain size (an annealed

structure); other times a uniform moderately coarse sorbitic structure with no free ferrite is visible (apparently normalized and drawn). It has been noted that the relative percentage of fatigue failure areas and normal failure areas in the fracture — that is, the ratio between the smooth, wavy-marked area and the section broken suddenly — is related to the grain size. Coarse-grained steels are more brittle and generally break when the fatigue crack has progressed across only 10 to 25% of the cross-section, whereas the tougher, fine-grained steels may hold on until the fatigue crack occupies 95% of the section. This is the situation shown in Fig. 1.

Fig. 1 — Fatigue Failure in Shaft; Full Size. Fine-grained nickel-chromium steel held on until 90% of the cross-section had failed

This lengthy introduction is in effect a confession that the microscope seldom can identify positively the cause of a fatigue failure. This microscopist was therefore delighted to get one case which was clearly defined.

Examination of the fracture in the shaft in question disclosed numerous cracks around the keyway, and these had spread under fatigue stresses until they covered half of the shaft when the remainder suddenly broke by normal failure under overstress.

The section was cut in half, through the keyway, and a surface parallel to the axis of the shaft was given a metallographic polish. It was obvious during polishing that the material had been welded at the keyway and hence no inclusion count was made. The nital etch brought out the welded structure very sharply and the photomacrograph Fig. 2 was taken to show the details.

The bottom surface of the keyway is at the top of this picture. Slightly below this surface a sharply defined line marked *A* is observed. This represents the junction of a second weld with a previous weld deposit. A line of oxide along the junction plus the straightness of this junction shows that the second weld was very poor, with no proper interpenetration of the two deposits.

Apparently what happened was that the keyway had become oversize and a workman, probably under the guidance of an economy-minded foreman, had welded it once, cut it oversize, and then welded it again to correct the error in machining.

The metal in the first weld deposit is in the area between *A* and *B* (Fig. 1). Although some blow-

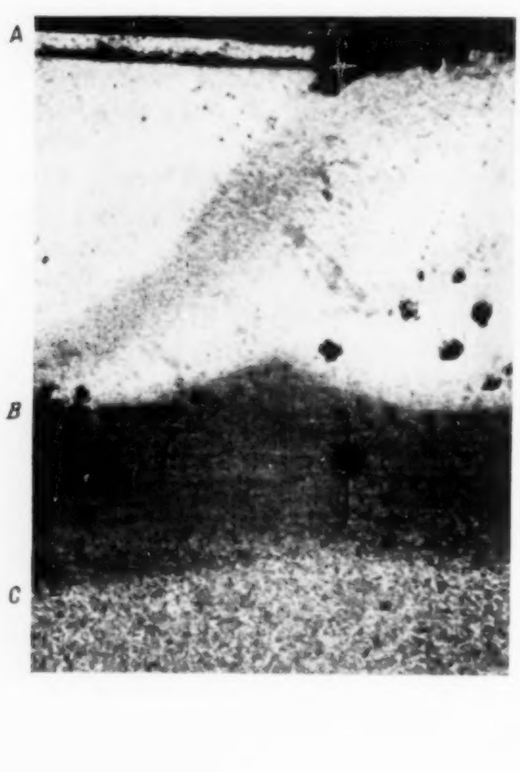


Fig. 2 — Micro, at 12 Diameters, of Section Parallel to Axis of the Shaft

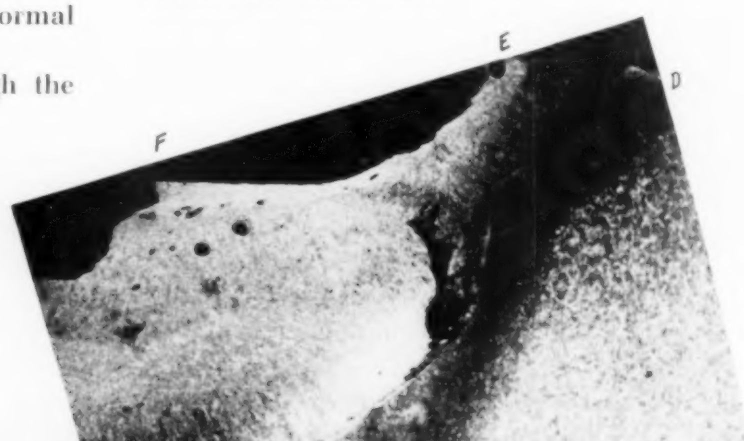


Fig. 3 Section Cut Transverse to Axis. E to D is cylindrical surface of the shaft; E to F is the keyway with round bottom

holes or pores are evident, this was a better weld since no straight line of demarcation is found between the weld and the base metal. The area near *B* shows some carbon diffusion from base metal into the weld metal (a low carbon steel) which diffusion evidently had occurred during the heating from the second welding operation.

From line *B* to line *C*, the structure of the base metal has been affected by the heat of both welding operations. The first weld heated this material above the critical temperature; rapid cooling by the flow of heat into the cold shaft below produced a martensitic structure. The second weld was too far away to heat the metal above the critical, but it did temper the martensite. This same zone, basically of hardened S.A.E. 3140 steel, also shows a sharp crack in the center of the micro. The crack could readily have been produced entirely by the thermal stresses accompanying the heating and cooling of the welding operation.

Below *C*, the original metal shows up with no marked structural change although there is a slight etching effect caused by heat at this depth. This base metal had a considerably coarser grain, A.S.T.M. No. 3, than is considered desirable, but this was certainly not the cause of failure.

Figure 3 was taken at right angles to Fig. 2, transverse to the rod axis and through one side of the keyway. The same zones are reproduced in this section although here the second, outside weld deposit is wider and thus more clearly defined. The outside cylindrical surface of the shaft extends from *D* to *E* and the keyway cut is from *E* to *F*. It is evident that the second weld, made to correct an error of some sort, covers the entire keyway and extends slightly beyond the edge of it.

"I conclude, Watson", said the metallurgical detective, "that thermal stresses from the welding operation formed the cracks in the heat affected zone of the alloy steel shaft. These cracks could be readily propagated by normally harmless fatigue stresses. Welding of alloy steels should of course be forbidden in shops whose workmen are as careless as these evidently were. If it is absolutely necessary to weld this steel, the only procedure which would result in a safe condition subsequently would be to preheat the shaft to at least 500° F. before welding and to give the complete shaft a stress relief anneal immediately afterwards at a minimum of 1150° F."

STRATEGIC METALS

from low grade American ores

MUCH WORK IS BEING DONE by the U. S. Bureau of Mines on the recovery of strategic metals, particularly by electrical means, from domestic ores existing in the regions surrounding the large western hydro-electric developments where cheap power is available. The following notes on this work are taken from the Bureau's Annual Report for 1940, recently issued:

Manganese — The electrolytic process developed in 1936 by the electrometallurgical section of the Bureau is in commercial operation at Knoxville, Tenn. Recent work is designed to improve this process. In normal operation of this cell, the accumulation of manganese metal at the cathode is accompanied by the formation of 40 to 55% as much oxide at the anode. Experiments have been made on the use of separate anolyte and catholyte circuits, anode coatings or coverings, and special alloy anodes. The second line of attack mentioned offers the best possibilities, and of many materials tried, canvas-duck diaphragms are as good as any. The exact function of the anode covering is not well understood, at present.

Chromium — Domestic chrome ores generally have too low a chromium-iron ratio to produce standard ferrochromium. The problem is to raise the ratio somehow or else to produce pure chromium. Several methods of attack were followed: (1) Electrolysis in fused baths, which offered no practical solution, (2) electrolysis in aqueous baths, (3) matte smelting, and (4) electrothermal smelting.

Extensive studies of methods used in the Orford nickel process showed that the chromium could not be concentrated in mattes. Encouraging results, however, have resulted from activities in the second category mentioned, pursuing the idea that electrolysis of trivalent chromium salts should give at least twice the 20% current efficiency normally found in commercial plating from chromic acid baths. It was found that chromium can be extracted rapidly and efficiently (97%) from the abundant Montana chrome ores by dissolution with sulphuric acid in the presence of manganese dioxide. Considerable successful effort is being spent on purification of this leach liquor. Its electrolysis, using insoluble anodes, has been worked out to a point that electrolytic chromium has been produced from trivalent chromium salts at current efficiencies as high as 63%. It is believed that 45% could be attained on a commercial scale, which is much better than in a standard chromic acid plating bath. Electrolytic chromium is well on its way toward practical realization. *(Cont. on p. 110)*

INSPECTION OF STEEL

as to its composition

By Harry B. Pulsifer
Metallurgical Engineer
Cleveland, Ohio

IT IS A COMMONPLACE to say that the inspector must make sure that the metal tendered meets the specification as to chemical composition. There is no substitute for quantitative chemical analysis, to be made on a representative sample by competent analysts. The matter of "representative sample" is where the inspector comes in, and some remarks about proper procedure in taking it will be in order. There are also numerous less precise indications that advertise the general nature of a steel as it reacts to various fabricating processes, and it is well to describe them since the watchful workman and inspector can often cull out tramp pieces of metal of proper size but incorrect analysis.

Taking a Proper Sample

If it is so specified a suitable sample must be obtained and forwarded to the proper laboratory for analysis.

The object from which the sample is taken should be cleaned of scale, coatings, oil or grease, or any other outside adhering material so that the metal itself will be clean. Grease, oil and some lubricating coatings can be removed with solvents (carbon tetrachloride or light solvent being convenient) but the final cleaning is preferably a dip in hot dilute hydrochloric acid solution to rid the surface of scale, rust, lime, or carbonaceous compounds. The material is then rinsed, dried, and taken to the milling machine where the sampler takes enough cuts across the entire cross section to accumulate a two-ounce sample of fine chips.

The milling machine should be clean about the cutters and collecting scoop, the cutters be sharp, and the feed so regulated that the metal is not burnt. An inspector is at liberty to choose his samples and see that the millings from the samples are put in the packets which he forwards, properly labelled, to his laboratory. It is the inspector's responsibility to see that the sample put in his packet comes from the pieces he originally selected or stamped.

Care should be taken to see that the sample, if possible, represents the material in its entirety. This is done by milling across the entire section. Samples taken largely from a surface, or from a core, or from one edge, may be misleading. Wide strip can be folded upon itself into a tight pad which is then milled across its end in the machine.

Rapid Indicators

Since the returns from the chemical laboratory may require several hours or even days, there are a variety of rapid qualitative tests

that can be used to identify the material. At other times it is advisable to check the uniformity of a lot of objects; then rapid testing is very desirable. These rapid tests involve many properties of materials and new tests are added from time to time. Some of the more convenient ones in current use will now be briefly described.

The Bend Test — For many smaller objects, and elongated ones such as rods, wire and strip steel, the material may be bent upon itself or about a radius, such as its own diameter. Since the inspector is presumed to know the way in which the specified material *should* bend, he can rapidly check its conformity to type.

Thus, soft and annealed material should bend upon itself without cracking. Even high carbon steel in good forming condition may be expected to take this test. If it will not, the nature of the deficiency can be traced by hardness tests, micro-sections or sulphur prints.

Electric and openhearth steels are much more plastic than bessemer steel and bend far better. Medium and high carbon steels with the carbide present as pearlite bend rather poorly, so that lack of plasticity may be the fault of the heat treatment rather than off-composition.

Any steel with a hard surface, or even thin skin of harder nature, bends with surface cracking. This is a very important condition to note. Surfaces damaged by sulphur-bearing gases during the manufacture of the steel crack abundantly on bending. Surfaces that are rough, pitted, chattered or even minutely imperfect cannot be expected to bend properly.

Hardness After Quenching — An excellent way to check the composition of steel is to water quench a small and preferably thin sample and determine its hardness. A pan of water is placed at the furnace door and the small piece at the proper hardening temperature is quickly flipped into the quench. Steels with 0.60% carbon and up should harden from 1450° F., steels with 0.30 to 0.60% carbon should harden from 1500° F. and the lower carbon steels from around 1600° F. (This temperature required for hardening is in itself a means of distinguishing steel, as will be shown in more detail later.) By referring to a chart showing quench hardness vs. carbon content, such as the one by Burns, Moore and Archer reproduced in METAL PROGRESS for June 1941, page 722, the carbon content can be approximated. No matter what the alloy content, low carbon steels cannot show the hardness of high carbon steels, nor can high carbon steels fail to harden except in most unusual cases. Maximum hardness after quenching is about:

CARBON CONTENT	ROCKWELL HARDNESS
0.05	C-30
0.10	C-39
0.15	C-44
0.20	C-49
0.25	C-53
0.30	C-56
0.35	C-59
0.40	C-61
0.50	C-64
0.60 and above	C-66

The Spark Test — One of the quickest tests for composition, and one that is extremely valuable, is to hold a piece of the metal in question against a fine grinding wheel at speed and watch the nature of the sparks. Pure iron gives long streamers with few spurts or forks; the forking of the streamers begins to be pronounced with 0.15% carbon; compound forking or flowering bursts are in evidence with 0.45% carbon while 0.95% carbon toolsteel gives brilliantly clus-

AN immediate shortage of skilled inspectors for the Government defense program led many ⊕ Chapters to present lecture courses on the elements of metal inspection — courses that were attended literally by thousands of men. It became apparent that a small text on the practical aspects of inspection would be very useful, and such a project was welcomed by the Ordnance Dept., U. S. Army. The Board of Trustees ⊕ therefore authorized the production and sale of such a book at cost, as one of the Society's contributions to the national effort. The services of Harry B. Pulsifer were retained as author, and the handbook on steel inspection (of which this article is a part) will be ready on August first. Mr. Pulsifer has had years of experience in the production of quality steel with American Steel & Wire Co., and with its use as metallurgist for Ferry Cap & Set Screw Co. His clear presentation of many items seldom seen in print is also influenced by his former experience as a college instructor.

tered bursts. Many laboratories have standard carbon test wires, increasing by 0.05% steps from carbonless iron to 0.70% carbon, as well as the other common alloy steels, available for comparison so that various materials can be identified without difficulty.

Much information on the spark test is contained in an article of that title in ⚙ Metals Handbook, 1939 Edition, page 773. Diagrams showing the characteristic sparks are shown in a Data Sheet in October 1940 METAL PROGRESS, page 386-A. The adjoining table is reproduced from the latter source.

the core of a casehardened piece the annealed sample can be put in a lathe and the outer layer turned off. The crisp and brittle chips change to one long and endless chip as the soft core is reached. This method of differentiation and segregation is sometimes preferable to drilling out the core, for the separation of the outer carburized zone is demonstrably certain.

The "machinability rating" of a steel can be checked by a power hack saw cut, if the blade cuts cleanly without rubbing on the stock. The cutting time decreases as the machinability increases.

Characteristics of Spark Stream From Representative Alloys

Metal	Volume of Stream	Length of Stream *(a)*	Color of Stream		Quantity of Spurts *(b)*	Nature of Spurts *(b)*
			Close to Wheel	Near End		
Wrought iron	Large	65 in.	Straw	White	Very few	Forked
Machine steel	Large	70	White	White	Few	Forked
Carbon toolsteel	Moderately large	55	White	White	Very many	Fine, repeating
Gray cast iron	Small	25	Red	Straw	Many	Fine, repeating
White cast iron	Very small	20	Red	Straw	Few	Fine, repeating
Annealed malleable iron	Moderate	30	Red	Straw	Many	Fine, repeating
High speed steel	Small	60	Red	Straw	Extremely few	Forked
Manganese steel	Moderately large	45	White	White	Many	Fine, repeating
Stainless steel	Moderate	50	Straw	White	Moderate	Forked
Tungsten-chromium die steel	Small	35	Red	Straw *(c)*	Many	Fine, repeating *(c)*
Nitrided nitralloy	Large (curved)	55	White	White	Moderate	Forked
Stellite	Very small	10	Orange	Orange	None	
Cemented tungsten carbide	Extremely small	2	Light orange	Light orange	None	
Nickel	Very small *(d)*	10	Orange	Orange	None	
Copper, brass, aluminum	None				None	

(a) Figures obtained with 12-in. wheel on bench stand, and are relative only. Actual length in each instance will vary with grinding wheel and pressure.

(b) "Spurts" are the sparks (seemingly small explosions) that occur at intervals on the carrier lines.

(c) Spurts are blue-white.

(d) Some wavy streaks may be observed.

Because of its quick and certain response the spark test is widely used. It is also invaluable in detecting surface carburization or decarburization (effects, which, by the way, should never be allowed to obscure the test on the underlying stock).

Tool Tests — A file is extremely useful to detect hardened surfaces, even slight skin thicknesses. It is the quickest way to detect soft spots on hardened pieces, while one would surely soon learn to differentiate the free-cutting materials from the tough and tearing ones.

The lathe chip of a high carbon steel is greatly different from that of a low carbon steel, especially after normalizing. Thus, in getting a sample for chemical analysis from

Scale Characteristics — Operators or inspectors often notice that hot metals scale at different rates and in different ways, each scale having certain flaking characteristics. Low carbon steel scales deeply, while high carbon scales lightly under similar conditions. Unusual scaling of a lot of steel or wide variation in the pieces of any lot should be grounds for immediate investigation.

Magnetic Response — Ordinary iron and the carbon steels are highly magnetic up to the so-called Curie point. This is about 1335° F. for steels containing 0.80% carbon and over, and gradually increases to 1418° F. for 0.45% carbon steels and lower. The austenitic steels, of which the most common is the 18% chromium 8%

nickel stainless steel, are non-magnetic. The 18% chromium-iron and the steels with 12% or less chromium are magnetic.

The "carbometer" and "carb-analyzer" are instruments for quickly determining the carbon content by magnetic means on pencils of steel poured at the openhearth or electric refining furnace. They can hardly be called inspection methods, but electrical methods are coming into use to check the uniformity of composition and structure of identically shaped objects by making two of them act as cores of a balanced electrical circuit. If the pieces exactly conform in size, composition, and treatment, the circuit remains in balance, but if a different composition or treatment exists in a similar piece that replaces one of the cores, then the circuit unbalances and this fact registers on electrical indicators, oscillograph, or by amplification to earphones. Continuous testing of high grade strip, wire or tubing by similar methods is now being done.

Spot Test for Nickel — The beautiful and characteristic carmine color of nickel precipitated by di-methyl-glyoxime is widely adapted for rapid spot testing of steels containing this element. The cleaned stock is arranged in a row and a drop of nitric acid placed on each piece. A strip of paper saturated with the reagent and dried is then touched in successive spots to each drop of acid. Not only the sure presence of the nickel but its approximate percentage is disclosed by the depth of carmine color.

Solution Rate and Acid Attack — The analytical chemist knows that bessemer steel chips dissolve in concentrated nitric acid with violence, openhearth and electric carbon steels with moderation, and highly alloyed steels rather slowly. An adaptation of this procedure is available for rapid testing by dipping the smoothed ends of bars, rods or wires in a dish of hot one-to-one hydrochloric acid. Bessemer and high sulphur steels color black on the ends very promptly. Screw stock and high sulphur laminated steels shortly appear porous on the ends. The rimmed steels disclose their outside layers of lower carbon ferrite. Capped steels etch more deeply than killed steels. The killed high carbon and alloyed steels remain brightest longest. Pipes and patterns appear promptly.

To distinguish between ordinary steel and stainless steel, when the characteristic dull, leady luster of the latter cannot be relied upon, dip the questionable materials in an acidified solution of copper sulphate. Carbon and alloy steels quickly become plated with copper; stainless steels remain bright as before.

Sulphur Prints — Sulphur prints are made in a dark room. Smooth the section to be tested and press it for one minute against a piece of photographic print paper moistened with dilute sulphuric or hydrochloric acid solution. The paper is then removed, cleared of silver salts in a hypo solution, washed and dried. The print will keep indefinitely. A second print from the same surface is weak and of small account, but by re-surfacing to a few thousandths another good print can be obtained.

Sulphur prints show the amount and distribution of the sulphides in the metal. The free-cutting steels afford strong prints while many toolsteels naturally give very weak prints.

Spectroscope Lines — The use of the spectroscope has developed rapidly along certain lines of quantitative chemical analysis. In the metallurgical field it is also very handy to check manganese, chromium, molybdenum, nickel, and columbium in an approximate way. That is, it is practical to distinguish a straight carbon steel from an alloy steel; different grades of alloy or stainless steel can also be separated or identified. This can be done because it is not usually necessary to know *how much* of an alloying element is present in order to identify the grade of steel. This test is rapid and a keen eye soon learns how to compare uncertain stock with standard pieces.

Differential Quenches — One of the interesting facts about some of the well alloyed steels is the low temperature at which they will harden after having been heated hot enough to get their carbides in solution. Practically all steels begin to dissolve their carbides at 1340° F. or lower, and at 1500° F. most heat treating steels will have all of their carbides in solution and be ready to quench when the piece is uniformly at that temperature.

Again, on cooling, some of the high manganese, nickel and nickel-chromium-molybdenum steels only start to transform or precipitate their carbides at such low temperatures that it is possible to cool pieces of mixed grades to a temperature such that the carbon steels will not harden and the alloyed steels will, when water quenched from this temperature. The carbon steels will not harden because they have already precipitated their carbides as coarse particles at the high temperature.

This test may be used to check compositions — all uniformly high manganese or alloy steel, or mixtures. In fact, the principles underly the practice of hardness testing all pieces of critical importance after their final heat treatment. Any piece of hardness beyond acceptance limits, either above or below, is thrown out because (among other things) it is quite likely made of steel far enough from specified composition to vitiate its response to routine heat treatment. A data sheet excellent for this test is reprinted on the opposite page. To this may be added the following figures for Amola steels:

	Ac_1	Ac_3	Ar_3	Ar_1
A-4023	1360	1540	1430	1240
A-4027	1360	1500	1400	1230
A-4032	1350	1495	1390	1225
A-4037	1320	1410	1340	1210
A-4042	1315	1405	1330	1205
A-4047	1310	1400	1320	1200
A-4065		1390	1220	1190

Micro Patterns of Etched Sections — It is not impossible to prepare a smoothed and properly etched surface of a section of metal for microscopical observation in four or five minutes, provided it can be cut off quickly or is already a small piece. Smoothing by hand is very rapidly done by the skilled operator; the newly developed methods of electrolytic polishing are even more rapid.

One can often estimate the carbon content, high or low sulphur content, and uniformity of composition fairly rapidly from what he sees magnified say 100 dimensions. Moreover, the cold-worked, annealed, or treated condition will be apparent at a glance. In many cases a micro-examination is an essential supplement to the chemical analysis, especially when surfaces are deeply changed by corrosion, carburization or decarburization.

A micro-examination does not necessarily mean a long tedious preparation of the specimen and may be a relatively speedy and satisfactory approach to the information required.

STAR GAZING

By Joseph E. Foster

Champaign, Ill.

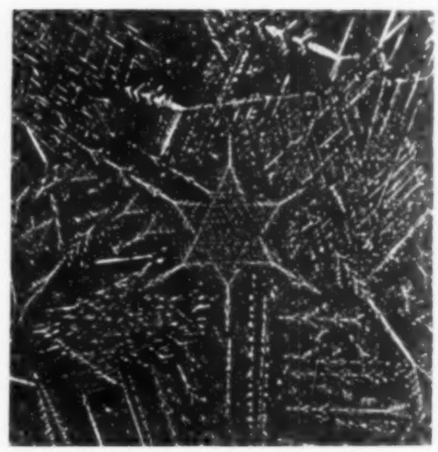
COMING upon this apparition, when examining babbitt at 60 diameters in the metallographic laboratory at the University of Illinois, I tried to think of some title other than that relic of the horse-and-buggy days about hitching your wagon to it. So to BARTLETT, and found something about star-eyed science (which gave the ego a fillip until these words of Isaiah were discovered: "The astrologers, the star gazers, the monthly prognosticators.")

Then there's this from Shakespeare:

"But I am as constant as the northern star,
Of whose true-fix'd and resting quality
There is no fellow in the firmament."

Or from Walt Whitman:

"Over all the sky — the sky! far, far out of reach, studded, breaking out, the eternal stars."



A technical explanation of the occurrence:

The white particles throughout the field and outlining the star are CuSn compound. The dark background is the ternary tin-antimony-copper eutectic. The etchant is ferric chloride.

A less technical explanation is by SAMUEL J. STONE (again copied from Bartlett's "Familiar Quotations"):

"Where did I come from, then? Ah, where indeed?
This is a riddle monstrous hard to read.
I have it! Why, of course,
All things are moulded by some plastic force
Out of some atoms somewhere up in space.
Fortuitously concurrent anyhow —
There, now!
That's plain as is the beak upon my face."

Approximate Critical Temperatures for S.A.E. Steels

by M.J.R. Morris, R. Sergeson and G.W. Gable; Central Alloy Division, Republic Steel Corp.

In most instances found by examining microstructure of quenched 3/8-in. discs of 1-in. round, taken from furnace at 20°F. increments. Grain size of steel unknown. Rate of heating and cooling about same as in furnace-cooling for commercial annealing

Number	On Slow Heating			On Slow Cooling		
	Ac_1	Ac_2	Ac_3	Ar_3	Ar_2	Ar_1
Carbon Steels						
1010	1350	1405	1605	1570	1400	1255
1015	1355	1410	1585	1545	1395	1265
X1015						
1020	1355	1410	1570	1535	1395	1260
X1020						
1025	1355	1405	1545	1515	1405	1255
X1025						
1030	1350	1405	1495	1465	1405	1250
1035	1345		1475	1455	1395	1275
1040	1340		1455	1415		1275
X1040	1340		1450	1340		1270
1045	1340		1450	1405		1275
X1045	1335		1420	1330		1270
1050	1340		1425	1390		1275
X1050	1335		1400	1330		1270
1055	1340		1425	1390		1275
X1055	1335		1400	1330		1270
1060	1340		1410	1370		1275
1065	1340		1385	1345		1285
X1065	1335		1380	1330		1280
1070	1345		1370	1340		1280
1075	1350		1365	1340		1280
1080			1360	1285		
1085						
1090			1360	1285		
1095			1360	1290		
10150*			1355	1290		
Free Cutting Steels						
1112	1355	1410	1590	1545	1395	1265
X1112						
1115						
1120	1355	1405	1550	1510	1400	1255
X1314						
X1315	1345	1420	1520	1495	1370	1245
X1330						
X1335						
X1340						
Manganese Steels						
T1330	1325		1480	1340		1160
T1335	1315		1460	1340		1165
T1340	1315		1435	1310		1160
T1345	1315		1410	1300		1160
T1350	1310		1400	1255		1105
T1360*	1305		1405	1200		1095
Nickel Steels						
2015	1375	1475	1575	1450	1400	1215
2115	1345	1455	1525	1475	1380	1195
2315	1300	1350	1440	1350	1260	1100
2320	1285	1345	1420	1235	1160	920
2330	1275	1315	1400	1180		1050
2335	1275		1375	1180		1050
2340	1280		1360	1180		1060
2345	1280		1350	1180		1060
2350	1280		1340	1180		1070
2515	1250	1335	1420	1220	1140	825
2520*	1240	1340	1390	1175	1025	825

*This number not in the official S. A. E. list

Number	On Slow Heating			On Slow Cooling		
	Ac_1	Ac_2	Ac_3	Ar_3	Ar_2	Ar_1
Nickel-Chromium Steels						
3115	1355	1400	1500	1470	1380	1240
3120	1350	1400	1480	1455	1380	1230
3125	1350	1395	1465	1400	1380	1220
3130	1345	1380	1460	1360		1220
3135	1340		1445	1300		1220
3140	1355		1415	1295		1220
X3140	1350		1430	1300		1240
3145	1355		1395	1295		1220
3150	1355		1380	1275		1215
3215	1350	1410	1465	1415	1350	1240
3220	1350	1415	1460	1405	1355	1240
3230	1340		1435	1395		1240
3240	1335		1425	1280		1240
3245	1345		1400	1270		1225
3250	1340		1375	1255		1200
3312	1330	1370	1435	1240		1160
3325	1335	1365	1400	1230		1160
3330*	1320	1360	1380	1225		1145
3335	1310		1360	1200		1100
3340	1290		1380	1180		1100
3415	1330	1370	1425	1340	1300	1220
3435	1290		1380	1200		1150
3450	1290		1360	1200		1100
Molybdenum Steels						
4130	1395	1435	1485	1405	1395	1280
X4130	1395	1435	1480	1405		1250
4135	1395	1440	1475	1380	1360	1280
4140	1380		1460	1370		1280
4150	1365		1395	1355		1280
4340	1350		1425	875		725
4345	1345		1415	875		725
4615	1335	1400	1485	1400	1320	1200
4620	1335		1470	1390		1175
4640	1320		1430	1300		1125
4650*	1315		1410	1260		1125
4815	1300		1440	1310		800
4820	1300		1440	1260		760
Chromium Steels						
5120	1410	1460	1540	1470	1420	1295
5140	1370		1440	1345		1280
5150	1330		1420	1280		1220
52100	1340		1415	1315		1280
Chromium-Vanadium Steels						
6115	1420	1460	1550	1450	1380	1300
6120	1410	1460	1545	1440	1380	1300
6125	1400	1440	1490	1390	1360	1295
6130	1390	1440	1485	1370	1340	1285
6135	1390		1480	1370		1280
6140	1390		1455	1375		1295
6145	1390		1450	1375		1290
6150	1385		1450	1375		1270
6195	1370		1425	1360		1300
Tungsten Steels						
7260	1360		1430	1370		1310
Silicon-Manganese Steels						
9255	1400		1500	1380		1320
9260	1400		1500	1380		1315

A NEW STAINLESS STEEL

for the paper pulp industry

By G. C. Kiefer
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DURING THE LAST 15 years the alloys of chromium and chromium-nickel commercially known as stainless steels have definitely proved their value in the paper industry.

As might have been expected, several failures in service were encountered in the earlier applications, primarily due to the lack of knowledge both as to properties and correct methods of fabrication. In the last few years increased knowledge and improved technique in fabrication have been reflected in the excellent performance of these alloys.

While the stainless alloys comprise a group of at least 40 different types, varying in chromium and nickel contents with or without other elements, such as molybdenum, columbium, titanium, or silicon, we will confine our present remarks to three types that are now being used in sulphite pulp equipment, as follows:

Type No.	Carbon	Chromium	Nickel	Molybdenum
308	0.08 max.	19 to 22%	10 to 12%	
317	0.10 max.	18 to 20%	12 to 14%	3 to 4%
329	0.10 max.	25 to 30%	3 to 5%	1 to 1.5%

As noted in the subchapter by J. D. Miller in The Book of Stainless Steels on the requirements of the paper mills, it was early found that the all-purpose alloy 18-8 was too corrodible in the somewhat contaminated sulphite solutions found in the mills. A little experimentation indicated that corrosion resistance increased as the total of chromium and nickel content increased; consequently the demand for 18-8's on the high side of the analysis led to the use of Type No. 308. Likewise 4% molybdenum was specified in metal for digester linings as early as 1933, with excellent results in additional corrosion resistance; hence Type No. 317. A great deal of information about these two alloys can be found in The Book of Stainless Steels. Type No. 329 is a more recent adaptation of the simple 28% chromium-iron alloy (Type 446), and some data as to its properties will now be given.

Type 329 is likewise similar to this latter chromium-iron alloy in that its structure is ferritic and it cannot be hardened by rapid cooling from elevated temperatures. Slow cooling from elevated temperatures or prolonged heating in the range of temperatures from 700 to 1400° F. lowers the notched-bar impact figure; on the basis of a few tests, alloy No. 329 appears to be even more susceptible to this loss of impact toughness than the regular 28% chromium alloy, and the range of temperatures in which the action can occur extends to as high

Properties of Wrought Stainless Steel, Type 329: High Chromium, Low Nickel

Heat, °F.	Time	Cooling	Yield Strength	Tensile Strength	Elongation in 2 In.	Reduction of Area	Izod Test; Ft-Lb.	Brinell Hardness
As hot rolled			88,015	127,000	22.7	47.8	10 to 15	
1650	6 hr.	Water	69,860	104,630	28.8	55.1	10	
1925	30 min.	Water	80,000	107,000	33.0	55.0	56	228
1925	30 min.	Air	68,000	109,000	25.0	36.0	36	217
1600	3 hr.	Slow					10	
1900		Slow					2	
1900	45 min.	Water					65	
1950	45 min.	Water					53	
2000	45 min.	Water					62	
2050	15 min.	Water					64 to 112	
2050	45 min.	Water					41 to 60	
2050	1 hr.	Water					35	
2100	45 min.	Water					86	

as 1650° F. (In referring to this phenomenon, it should be borne in mind that these alloys exhibit this lower impact toughness only when cooled to the vicinity of room temperature and tested at that temperature, and that when tested at working temperatures above 200° F., they show normal toughness.)

In order to obtain the best mechanical properties in the straight 28% chromium alloy, it is necessary to cool it rapidly from 1650° F. after holding at temperature for at least an hour. Heating to temperatures over 1800° F. results in excessive grain growth and brittleness from this cause. In order to obtain a high impact toughness in room temperature tests on Type 329 stainless steel, it is necessary to cool rapidly from the vicinity of 2000° F., because cooling from the temperature range recommended for the straight 28% chromium-iron results in a material with low notched-bar impact tests.

Other properties are very similar to those found in regular 28% chromium alloys. The table above gives a summary. These properties are those available in various rolled forms, such as bars, thin plates and tubes. Castings of a similar analysis (28% Cr, 3.5% Ni, 0.7% C, 0.7% Si max., 1.0% Mo max., with titanium or nitrogen as a grain refiner) have been used in the north European paper industry for some time, as described by John Sissener in Metal Progress for October 1937.

Accelerated tests in sulphite liquor — 4% sulphurous acid containing 1% sodium bisulphite at 150 lb. pressure (360° F.) — show the following corrosion rates in milligrams per square inch of surface per hour of exposure:

Type 304 (regular 18-8)	0.60 mg.
Type 308	0.20 mg.
Type 317	0.33 mg.
Type 329	0.21 mg.

The corrosion rates for the last three are fairly close together and low enough so that the selection of one rather than the other has usually been based on the experience of the mill superintendent under his existing service conditions. Attention is directed, however, to the marked difference in corrosion resistance between the so-called regular 18-8 and the Type 308 alloy. This pronounced resistance of Type 308 is further emphasized in tests conducted at the Virginia Polytechnic Institute by L. E. Ward, who determined the corrosion resistance of various metals to the fatty acids recovered from kraft pulp waste liquors. Regular 18-8 alloy was penetrated at the rate of 0.061 in. per

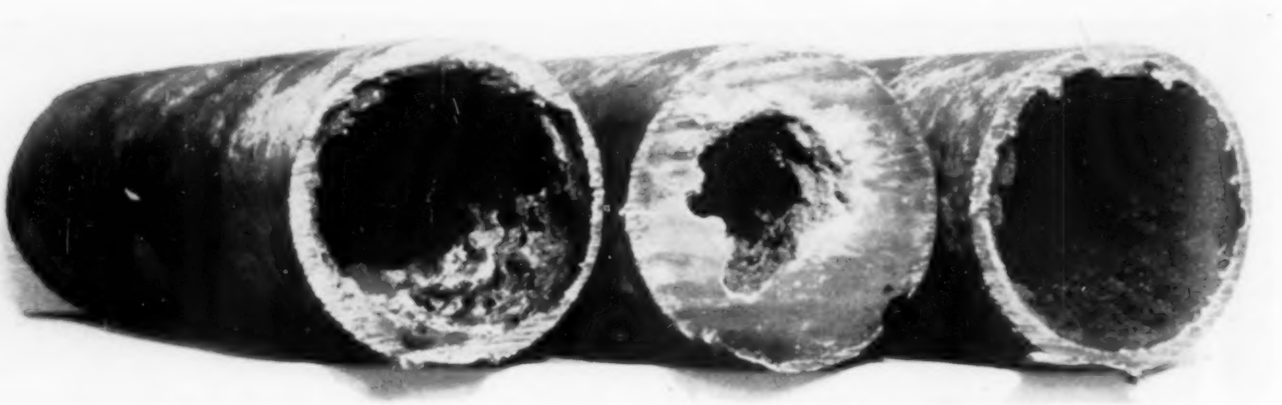


Fig. 1 — Accumulations of Sodium Sulphate and Organic Matter in Heat Exchanger Tubes

year, while Type 308 alloy showed only 0.0010 in. penetration per year.

The high alloy content of Types 308 and 317 materially retards precipitation of harmful carbides at the micro-grain boundaries when the alloys are welded, and thus lessens their susceptibility to intergranular attack. Since *time* is an important factor in this phenomenon of carbide precipitation, the cross-section to be welded has a marked influence, so the adjusted composition in No. 308 will only be economically effective when comparatively light sections or clad plates are to be welded. Experience has shown that solid plates or castings up to ½ in. can be welded without precipitating harmful carbides, and this is a thickness beyond those used for sulphite equipment. Therefore, Type 308 can be used in most cases where welding is involved.

For greater thicknesses where welding is necessary, or where the repair or revamping of this heavy equipment by welding might occur, the columbium or titanium modification of the alloy is suggested. Type 308 with columbium should also be used where the fabrication is to be stress relieved at moderate temperatures (800 to 1600° F.). (Where the titanium modification is used and welds cross each other or where single welded equipment is to be stress relieved, a columbium-bearing welding rod must be used, as very little of the protective titanium remains in the deposited weld metal.)

We are not suggesting, however, that Type 308 alloy should be used for all equipment in the pulp making industry. Selection should be governed by the corrosive conditions encountered. Generally speaking, Types 308 and 329 offer the highest resistance to corrosion where the liquid phase is encountered, or in the gaseous phase at temperatures above the dew point. Type 317 alloy is more resistant to service conditions where condensation occurs, or where the sulphuric acid content of the sulphite liquor is abnormally high; it is also satisfactory for hypochlorite bleaching solutions and for pulp washing equipment handling material after a chlorine bleach.

Correct applications of these alloys to specific parts of digester equipment, blow pits (perforated bottoms and targets), acid recovery systems, liners for pulp washing troughs, and bleaching equipment have been established from service experience. There are five experimental digesters fabricated from Type 308 in operation; they have been in entirely satisfactory service for one to eight years. There are also large amounts of the same alloy in the form of cast valves, seamless tubing and rods in the acid lines both hot and cold, in heat exchangers, collector rings, screens and similar digester accessories.

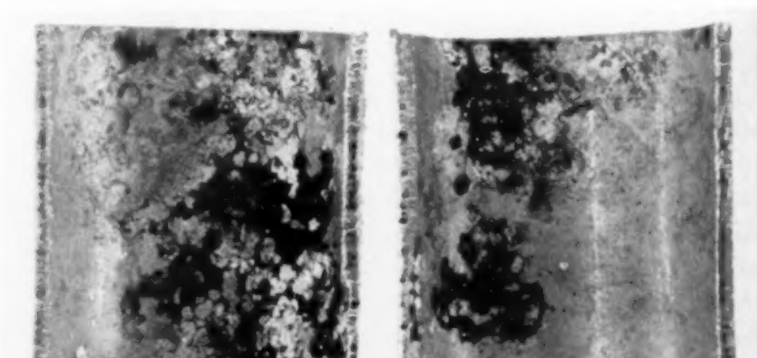


Fig. 2—Inside Surface of Damaged Heat Exchanger Tube, Split and Cleared of Deposit. Dark areas are deep pits that grew under tightly adhering foreign matter that absorbs oxygen

Type 317, the molybdenum alloy, can be used in almost every place where Types 308 and 329 are used. Because of its higher price, however, greater economy can be obtained by limiting it to those parts demanding particular corrosion resisting characteristics, or by using it as a thin cladding to protect common carbon steel.

For example, Type 317 is far more resistant to sulphuric acid solutions than the other two alloys. Since sulphuric acid is usually formed when moist sulphur dioxide condenses, Type 317 should be used in all top relief lines, flumes, blow pit sections above the pulp line and various parts of acid recovery systems where condensation is likely to occur. In some sulphite mills which lack close control of the sulphite liquor, sulphuric acid is present in higher amounts than are

normally encountered. The limiting concentration of sulphuric acid for safety against Types 308 and 329 is approximately 0.25%.

Type 317 with its sizable molybdenum content is also less susceptible to pitting in solutions containing chlorine. It is therefore satisfactory for pulp washing equipment following chlorine bleaches where small amounts of hydrochloric acid generally develop in the wash water. Laboratory and service tests also indicate that it is resistant to calcium hypochlorite in either the alkaline, neutral or acid conditions. It is to be emphasized, however, that *none* of the stainless alloys mentioned are resistant to moist chlorine gas.

There are several difficult corrosion problems in the pulp industry which require careful consideration. Tubular heat exchangers may accumulate deposits of sodium sulphate and organic matter as shown in Fig. 1, under conditions not fully understood. Sometimes only the tubes in one or two exchangers of a large number using the same raw acid will be affected. It is essential that this deposit be periodically removed, else pits will form in the tube wall (Fig. 2). This is because the corrosion resistance of stainless steel is dependent on the maintenance of an invisible protective film of oxide. When stainless steel resists corrosion satisfactorily, any minor damage to this film is automatically healed. Deposits of many solid matters, especially organic materials that absorb and react with oxygen, prevent the re-formation of this protective film where it may be damaged, and localized corrosion occurs at those places.

In removing this deposit by mechanical means, the tool should not gouge or scratch the surface, as scratches form pockets in which deposits again rapidly accumulate and subsequent cleaning is made more difficult. If the equipment is all stainless steel, nitric acid can be used to remove sulphate deposits, as this acid will not attack stainless steel; in fact, it "passivates" the surface, adding to its normal corrosion resistance.

Another problem frequently encountered is the corrosion of metal tierods, bolts and screws when inserted in wood which is exposed to moist sulphurous atmospheres. The wood soon becomes saturated with acid and that part of the metal in contact with it is rapidly corroded, as shown in Fig. 3. The most satisfactory solution to this problem is to paint that part of the metal in contact with the wood with a good asphalt paint.

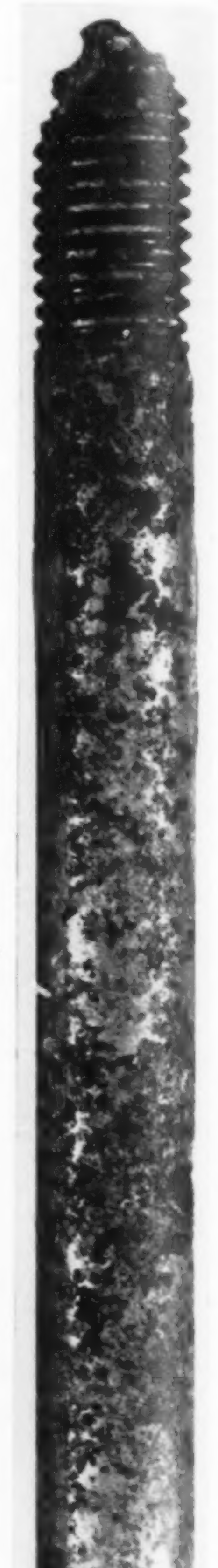
Something should be said about the use of stainless steel in pulp screens. Failures have been due either to the thin gage of the plate, the design, or the method of fabrication. These screens are made up in sections, joined to one another by spot welds, and are supported on bars that are slotted to make space for the joints between sections. The failures which we have investigated have resulted from fatigue cracks near the supports and the welds holding the screen sections together. The corrective is a change in design to distribute the working stresses more uniformly.

In the application of any of the metals or alloys a knowledge of their characteristics and properties is always desirable. The stainless alloys are probably the most useful materials developed by modern metallurgy, but it often happens that a lack of this understanding results in failure or at least a lowering of their useful life. The following brief suggestions are offered for the purpose of assisting those who fabricate or repair stainless steel parts:

A clean surface is necessary to obtain the maximum corrosion resistance. Chalk marks, grease, scale and other surface contaminations should be removed whenever it

(Continued on page 90)

Fig. 3 — End of Tie-rod, Eaten Away by Acid Absorbed by the Wood in Which Metal Rod Was Embedded



WEAR, AND WHAT CAN

be done about it

By Gordon T. Williams
Deere & Co.
Moline, Ill.

IN THIS EXCERPT from the series of lectures given last winter before the Tri-City Chapter, ⊕, I want to talk about one important thing I have hardly mentioned so far and that is *wear*, the thing that causes most machines and parts to be scrapped.

Let us define wear as "the undesired loss of dimension in service". That will include a few types of failure that we might not customarily think of as wear.

Of all the types of failure by wear, first, and most important, is *abrasion*, the grinding away of the metal surface. That is an obvious kind of wear. Wear of this sort is normally best counteracted by a high Rockwell, high Brinell, and high scratch hardness. That is a broad statement that can be shot full of holes, but bear in mind that our hardness numbers measure an aggregate property. A penetration hardness test reflects the hardness of those hard particles (at the location where the test was made) that are well enough supported so they resist being pushed in when the load is applied. Some materials at a given indentation hardness will show much better wear resistance than others. Typical is the usual finding that for a given Brinell hardness, higher carbon steel is more satisfactory for resisting abrasion. Why? Apparently because of the fact that carbon joins with the iron to make a hard carbide and there is a higher quantity of this iron carbide present in the higher carbon steels. Iron carbide is not only hard but has a great amount of wear resistance.

Even better than iron carbide as a wear resister is tungsten carbide. Very fine abrasion resistance in tools and die steels, several times that of hardened high carbon steel, can be obtained from a hardened 1.30% carbon steel which contains 3 or 4% of tungsten. The hardness of these die steels as indicated by the Rockwell machine may not be much greater, but the wear resistance against abrasion will be found considerably better under ordinary conditions. High hardness plus high carbon will ordinarily give the best resistance to abrasion in these tool and die steels.

The high hardness and wear resistance intrinsic to tungsten carbide is the basis of its use in wire drawing dies (as well as cutting tools). For these articles the powdered carbide is mixed with a little cobalt for binder, pressed into shape, sintered into a coherent mass, and ground and lapped to accurate size. (A pictorial story of these manufacturing operations was printed in METAL PROGRESS, Sept. 1939.)

Just how badly wear can dig into a part without completely shutting the machine down is shown in the first photograph of the remains of a carburized and hardened pinion. Abrasion

has done that. The hardness of the case on the unworn side of the remaining tooth stub is about Rockwell C-62, and the core (through which wear has largely gone) had a hardness in the neighborhood of C-30. Nevertheless, dirt in the oil used to "lubricate" this gear was sufficiently abrasive so that it and its mating gear wore down to the extent shown. Presence of dirt (which includes fragments of torn-off metal) is probably the chief factor in heavy abrasion.

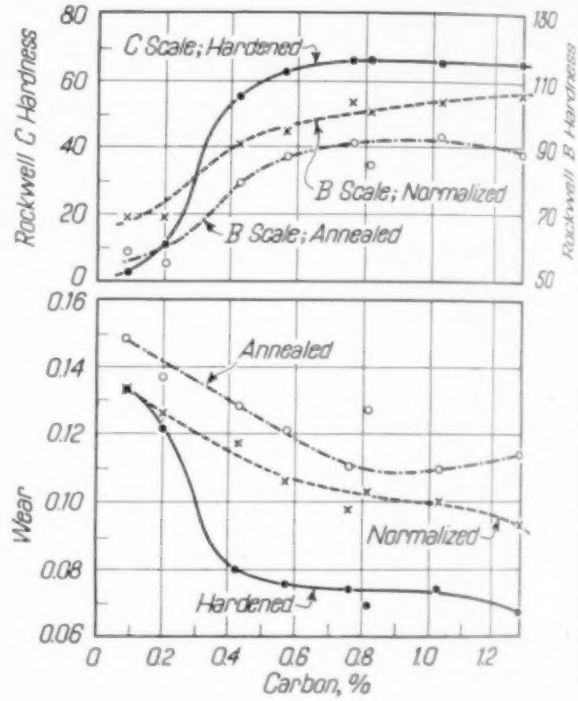
Wear Testing

There have been many testing machines designed for studying the wear resistance of various materials. There is no "standard"; all of the equipment is for specialized application. To mention a few: Tests have been made on agricultural implement parts by dragging them through sand or soil in an attempt to simulate field conditions. Laboratory tests cannot exactly duplicate or equal such a field service test. However, field tests are of less use when considering gear material, where the life of the part is contingent on lubrication and pressure. The best known wear test is the Amsler test, in which metal-to-metal contact between two disks is maintained under selected speeds and pressures, and the loss measured by weighing. Various so-called brake shoe tests have been developed; the one shown in the March 1941 issue of METAL PROGRESS was used for checking cylinder and piston ring wear.

Such specialized tests have proven excellent for special applications, but none of them tells the complete story of wear. There are so many factors (and so many of them non-metallurgical) that a metallurgical picture complete in itself is not likely to be obtained. Affected as it is by the nature of the film of lubricant, the entire problem is still most obscure, even to advanced researchers.

Surface finish is a major factor. The trend in the manufacture of bearings and liners is all toward the perfection of surface; the conclusion is therefore clear that — at least in bearings and journals — the least wear and longest life comes from the smoothest surfaces and the best fits. On the other hand, extreme smoothness in a gas engine cylinder will cause excessive "blow-by" and large oil consumption for a long breaking-in period. Cylinders and piston rings, and probably many other mating parts, require a little "gasket action", or incipient wear during the running-in period that adjusts the surfaces to small permanent size changes due

A Series of Carbon Steels Were Annealed, Normalized and Hardened, and Weight Loss (in Grams per 100,000 m-kg. of Work) Determined in Unlubricated Wear in an Amsler Machine. Generally speaking, wear resistance under these conditions is proportional to the hardness (Rosenberg)



to the working stresses and temperature changes.

A typical set of results with the Amsler machine is shown on the accompanying curves, grading steels of varying carbon content from 0.10 to 1.30% in the hardened, normalized and annealed condition against the wear loss. Low carbon steel shows, of course, very low hardening, and the wear resistance is likewise very little different from that of annealed or normalized steel of the same carbon content. With increase in carbon, the weight loss by unlubricated wear steadily decreases considerably to about 0.50% carbon and decreases much more slowly from there on. Throughout this range, the annealed steel shows the largest weight loss under test, but still the

Carburized Gear With Teeth Almost Destroyed by Abrasion Due to Gritty Particles Carried in the Oil

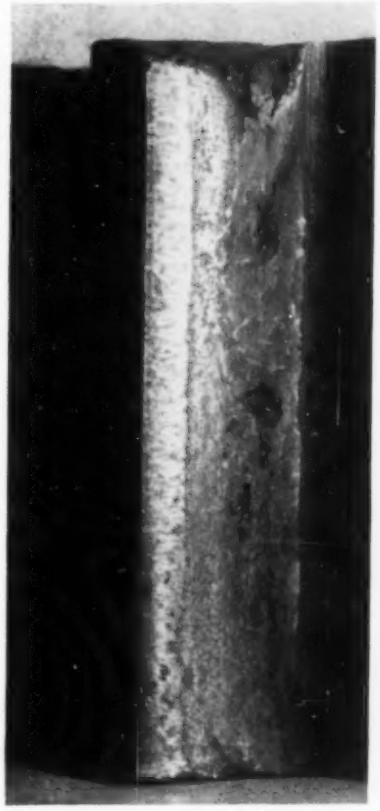
effect of increase in carbon content is seen. Normalized steels are intermediate.

These results are for just one set of conditions and do not tell us what will wear best in some specific machine part you may be thinking of.

Scoring and Galling

Another kind of damage causing loss of dimension is called *scoring*. Scoring we may think of as being very similar to abrasion, only the abrasive, instead of being dirt, is one or more hard particles sticking out from one of the surfaces — projections of metal. As the pieces slide past each other, a high spot on one may interlock with a slightly high spot on another piece, a fragment is torn out, and scoring will result. Scoring may occur very early, and once having made suitable tracks for the high spots on the mating part, may not go any further. All too frequently, it does go further, and then it is usually called by another name — *galling*. High finish is usually helpful in reducing scoring; of course, lubrication is an important factor.

The third type of wear just mentioned, galling, is metal-to-metal contact similar perhaps in origin to scoring, but it seems to be a little more than dragging a particle and plowing out a path. Galling implies a transfer of metal from one piece to another to build up a projection on one piece; the attached projection will score and, due to the large size of the particles involved, this condition usually continues fairly rapidly to destruction. To prevent galling, lubrication is again an important factor, as also is finish. Furthermore, there are chemical processes by which the surface of these metal parts may be so altered that galling, or metal welding from one piece to another, is interfered with. Those chemicals interfere with welding in the same sense that oxide will interfere with solder; that is, the surface is not chemically clean enough for metal-to-metal contact and welding to take place.



Pitting Failure of a Gear Tooth, Probably Due to Too Shallow a Case, and an Overload Beyond the Endurance Limit of the Underlying Lower Carbon Steel

If galling is severe enough to stop the sliding motion of two parts, it is known as *seizure*. Some high alloy steels are notoriously bad actors in the matter of galling and seizure, as for instance stainless steel of the 18% chromium, 8% nickel variety. Equipment which must expect rough handling — as in the oil fields — and deficient lubrication, must be designed with that in view, and combinations of metals selected that will cause the least damage if the bearings run dry.

Pitting of Carburized Gear Teeth

Pitting is another very important type of failure. A true case of pitting involves compression fatigue of the surface layers; the fatigue failures first occur below the surface in the weaker, lower carbon material there. (This will be discussed in detail in a later talk devoted to casehardening steels; it is clearly necessary for the stress resistance at all points under the surface to be in excess of the stress at those particular points.)

A typical fatigue failure by pitting on a gear tooth is shown in the last view. This pitting has not resulted in any great loss of dimension of the tooth as a projected whole, but it has resulted in a serious local loss of dimension. When the metal is gone from one of these pits, the load is increased on the remaining metal where contact and load application can still take place — and the damage spreads. Failure of this particular gear was, in my opinion, due to too shallow a case. It indicates, of course, the necessity for having ample case depth for ample stress resistance. In this connection, we must consider whether the stress comes from a static load or a repeated load, bearing in mind what we have already learned, that whereas the yield strength of a given steel is 65 to 70% of the tensile strength, the endurance limit is only perhaps 50% of the tensile strength.

To avoid the pitting type of failure, we must be sure that mechanical production has been as good as it should have been. We must avoid high spots, poor contact between teeth, poor rigidity of the assembly; when these are

taken care of we will have done most of the things that can be done toward avoiding the pitting type of failure.

Chipping, Flow and Corrosion

Chipping is another form of dimensional loss. It would hardly be called "wear" in the precise definition of the word. Chipping, of course, is a brittle failure, such as occurs with very hard steel. These discussions are being limited to steel, so we haven't said anything about cast iron, but I might mention that hard cast iron might fail by chipping in many applications due to brittleness. A lower Brinell material could perhaps last considerably longer before failing by abrasion. In other words, we may try to put more and more abrasive resistance into a part by giving it high hardness, only to find we have run into failures by chipping.

Flow is another form of loss of dimension. It certainly is not wear as we ordinarily think of it, but it is important and its mention fits best into this classification. There are many materials plastic enough that they will actually deform under the loadings they encounter. Again referring to gears, flow can occur in a condition wherein poor mesh or contact of gear teeth might cause a small portion of the tooth face of a soft gear to flow aside. In a hard gear, this kind of loading would perhaps result in breakage.

Corrosion certainly is not wear, and yet corrosion is loss of dimension and, as mentioned in the discussion on fatigue in the April issue, even slight corrosion is important mechanically as a producer of notches. Chemically produced notches by water corrosion (rusting) may be just as bad as notches that are produced by a poor machinist.

For those who might want to go further into the subject of wear, I would recommend the symposium held in 1937 by the American Society for Testing Materials. Various authorities gave papers on wear in their particular field, such as the automotive field, textile machinery, railroads, and these are as informative as any discussion of wear can be today.

In conclusion, I would like to quote a statement in that symposium. A speaker said that the loss of 5 lb. of metal was the difference between a brand-new and completely worn-out 5-ton truck! A 10,000-lb. article completely worn out by the loss of 5 lb. in the right places!

As to a theoretical explanation of wear, how it really happens, no information can be given. Some hold that there is momentary seizure between microscopic projections on the rubbing surfaces within the lubricating film, and these seized portions immediately are torn apart with the production of metallic star-dust. This assumption is not contrary to Dayton's researches at Battelle Memorial Institute, which show that if surfaces are "optically flat" and lubricated with non-corrosive oil that contains *no* abrasives, they can be run in a wear testing machine for an indefinite time without loss in weight or any observable wear markings.

Wear Is What Gets It! *(Photo by Rittase)*

CORRESPONDENCE

Die Castings
in the defense program

WASHINGTON, D. C.

To the Readers of METAL PROGRESS:

Prospective supplies of a number of strategic metals are insufficient to take care of this country's defense program and anticipated civilian demands. With maximum projected increases in production, the supplies of aluminum and magnesium will be inadequate for defense needs alone, as at present planned. A large percentage of the high grade zinc will be required for cartridge brass for American and British needs. Most of the large consumers of die casting alloys using zinc and aluminum are therefore either curtailing production or introducing substitute materials.

While the above remarks apply chiefly to primary metal, they are also true, in large measure, of secondary metal suitable for die castings. Scrap collection will alleviate this situation somewhat, but it is probable that at best this source will increase our available supply of aluminum by less than 10%, which will still mean a scarcity. Curtailment of 1942 model passenger cars to 3,460,000 units, together with substitutions in materials, will convert to defense use about 118,000,000 lb. of zinc (in brass, galvanized parts, and die castings) and 20,000,000 lb. of aluminum.

It is apparent that this program will have the effect of removing a large part of the chief market for die castings. Similar reductions or substitutions are in process in other fields where die castings were used, such as hardware, household appliances and electrical parts.

Based on the die casting industry's estimate of less than 15% of its productive capacity now being engaged in defense production, it would appear that either its personnel will have to be transferred to other defense production or the industry must secure more defense business to take the place of the defunct non-defense production. Additional defense business must be secured by the industry in the same manner as previous defense business or any other business, that is, by doing an efficient job of salesmanship on the advantages of die castings in effecting savings in materials, machines, man power and delivery intervals. The rapid growth in die casting production in recent years in highly competitive fields indicates that such advantages do exist, and merit increased use of die castings in defense production. Such advantages must be brought forcibly to the attention of defense procurement agencies.

There are at present about 125 die casting companies, with the majority relatively small producers. Most of the equipment is of the immersed plunger type which is only adapted to the zinc, lead and tin alloys. Relatively few producers have cold chamber machines suitable for brass and magnesium die castings, as well as aluminum, and less than a quarter of the producers have gooseneck type machines suitable for aluminum alloys. In 1940 the production of zinc base die castings was approximately 225,000,000 lb. and that of aluminum base alloys about 10% as much. If die casting productive capacity is to be utilized generally in the defense program, it will therefore either be necessary to demonstrate the suitability of zinc base die castings for additional defense applications, or to convert die casting equipment to make it suitable for the production of aluminum die castings.

Die cast products now acceptable to defense procurement agencies are *generally* made from aluminum — mostly parts for instruments, airframes, airplane engines or ordnance fuse parts. Discussion with Army and Navy Ordnance officials indicates the possibility of using dense, stable zinc die castings for some of the parts now made as aluminum *(Cont. on page 92)*

Proposed Standard Cutting Oil
available for test

Ann Arbor, Mich.

To the Readers of Metal Progress:

The Independent Research Committee on Cutting Fluids, which is affiliated with the ASM and headed by Joseph Geschelin, Chairman, has developed a reference cutting oil which is being distributed to members of the committee and to others for evaluation. The purpose of this reference cutting oil is to create a workable yardstick between laboratory and shop practice, as well as a basis for comparison of cutting oils, and a necessary standard auxiliary in testing metals for their machinability, and machining operations.

This reference oil was selected by the committee as the first step in the correlation program. Any organization interested in participating in this program can do so, and can get a supply of the reference cutting oil by writing to H. L. Moir, % The Pure Oil Co., Box 266, Winnetka, Ill.

The committee requests those interested to evaluate this oil by whatever means are at their disposal, whether it be by laboratory machines, or practical tests in the shop on machinability, tool life, finish, or any other criterion used by the participant.

All of the contributed material will be grouped and studied, and a correlation report given to those participating in the work. When the program is finished, the committee hopes to have an understandable correlation between shop and laboratory practice which will be of use to all.

Orlan W. Boston
Department of Metal Processing
University of Michigan

Expansion of Aluminum
production

Pittsburgh, Pa.

To the Readers of Metal Progress:

In the leading article in the February issue, discussing supplies of strategic and critical metals, the Editor made the following remarks about aluminum supply and demand, as viewed at the turn of the year:

"No shortage of ingot is anticipated. Fortunately The Aluminum Co. of America started many months ago on a large expansion program."

"Forging capacity: While there is more capacity than needed for military requirements at the present, a shortage is anticipated by July 1941."

"Adequate capacity exists, certainly as far as 1941 requirements are concerned, in the manufacture of extrusions and high strength tubing."

In view of the rapidity with which the projected defense effort can change, especially as regards aircraft production, you will perhaps be interested in a statement about these three critical forms of the strategic metal aluminum.

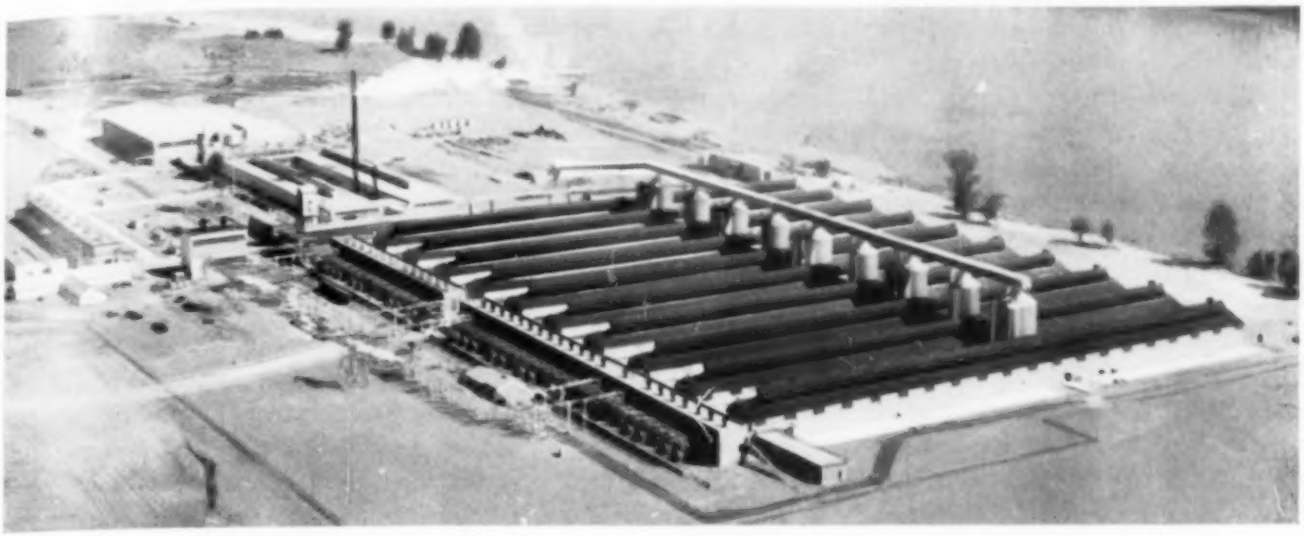
At present writing (June 9) there is no shortage of aluminum for national defense, although civilian applications have been materially curtailed. This reduction in civilian uses has affected many of you who have, because of the pressure of defense demands for aluminum, been forced to accept substitutes for the duration of the war.

Just how long we will be able to say "There is no shortage of aluminum for national defense" is problematical. There may be a shortage next month, in six months, in a year. It depends largely on plane production, not only for the United States but for Britain as well. According to a recent announcement by W. S. Knudsen, the expanded plane program will require an annual production of 1,600,000,000 lb. of aluminum, more than the whole world produced last year!

Aluminum production in the United States during 1939 was 327,000,000 lb. Domestic production at present is at the rate of nearly 600,000,000 lb. annually, and by July 1942 will reach 825,000,000 lb. a year. Until recently, Aluminum Co. of America was the sole producer of primary aluminum in this country, and by July of 1942 it will have completed a national defense expansion program which will more than double the production built up over a half century of operation. In 1942, the company's production of new metal will amount to more than 720,000,000 lb., and to reach this production, as well as to expand fabricating facilities, the company will have expended $200,000,000, all of which it is financing itself.

The accompanying view was taken of the new Washington Works at Vancouver, completed a little less than 15 months after ground was broken. Originally planned as a single producing unit for 30,000,000 lb. of ingot a year, operation at that rate was actually started less than six months after the first concrete was poured. The present plant contains five such units; power contracts for 162,500 kw. from the Bonneville dam have been signed.

A[illegible]minum Plant at Vancouver, Wash., Completed in 15 Months. Annual capacity: 150,000,000 lb. ingot



Equally important additions are being currently made in fabricating facilities.

The forging capacity in all the plants of Aluminum Co. of America has been increased as of June 9 by approximately 175%; extruded shapes capacity, sheet capacity, and tubing capacity have in each case been more than doubled; while wire, rod and bar capacity is up 130%, and sand casting capacity is now approximately 200% more than it was at the start of the war in September, 1939.

In 1937, in order to serve the airplane industry more effectively, the Aluminum Co. of America bought land in Vernon, a section of Los Angeles, and erected on it a sand and permanent-mold factory and forge plant. At the start of the war, the Vernon works had a capacity of 100,000 lb. of aluminum alloy forgings, and 424,000 lb. of sand and permanent-mold castings a month.

In the spring of 1940, an expansion of these facilities was announced, to include an extrusion works and a rivet plant as well.

Very shortly the sand and permanent-mold casting capacity will have been increased to 593,000 lb. a month (an increase of 40%), and the forging capacity to 450,000 lb. a month (an increase of 350%), while the new extrusion plant will be turning out shapes at the rate of 1,019,000 lb. a month, and the rivet plant producing at 70,000 lb. a month. By March 1942, the forging capacity of the Vernon works will have been increased an additional 50,000 lb.

The Lafayette, Ind., works of the company is also fairly new, having been placed in operation in January 1939.

When hostilities broke out, the Lafayette works had a capacity of 695,000 lb. of extruded shapes and 122,000 lb. of tubing a month. By October of this year, the floor space will have been increased 413%, and by December, the extruded shape capacity will have been expanded to 1,256,000 lb. monthly (six times the capacity in 1939), and tubing capacity will have reached 1,034,000 lb. a month (nine times the capacity of 1939). By April 1942, the tubing capacity will have been further expanded to eleven times the capacity in 1939.

Douglas B. Hobbs
Publicity Department
Aluminum Co. of America

Impact and Hardness Tests

Columbus, Ohio

To the Readers of Metal Progress:

I would like to comment on the article by Gordon T. Williams on the above subject (at least that portion wherein he points out the diverse opinions of metallurgists in the automotive industry) in Metal Progress for May.

The case of Riegel *vs.* Almen and Boegehold has been widely discussed, particularly to point out a discrepancy that is erroneously supposed to exist between the two viewpoints. My object in writing is to point out that we have a situation here which requires philosophical rather than metallurgical treatment.

Riegel was dealing with failures due to inadequate notch toughness while Almen and Boegehold were dealing with failures by fatigue. In the former case it is clearly correct that a correlation with the notched bar test should be

found, and in the latter case it is just as clearly correct that such a correlation should not be found, because non-existent. If ALMEN and BOEGEHOLD had been dealing with low temperatures and high normal stresses at the base of the tooth which cause a sudden failure instead of progressive failure, their results would have correlated with Charpy tests rather than with fatigue tests. By the same token, if they can be sure of having nothing but simple fatiguing stresses in their gears (as in springs), they need pay no attention to the Charpy values. They might also be able to save some money.

It is conceivable that a metallurgist going on instinct or experience will select steels and heat treatments that will give him adequate notch toughness for his service conditions though he does not use the Charpy test, but if he finds that he has "brittle" service failures on his hands (which indicate clearly that the break was sudden and complete) he should look to Charpy tests for his answer, rather than to tension or bend tests, or fatigue tests.

S. L. HOYT
Battelle Memorial Institute

Troubles With Stainless Steel
used as fourdrinier wire

CAMBRIDGE, MASS.

To the Readers of METAL PROGRESS:

The fourdrinier wire industry has standardized on bronze as the warp or tension member of the fourdrinier wire, and on brass as the shute or mesh making member. This has not been dictated by the lack of a desire to use different materials, but by experience with the inability of other materials to stand up under the operating conditions of paper-making.

Stainless steel has often been proposed as an ideal material, but the only successful application has been the mixing-in of the steel with the bronze warp. Such wires have established records of 100% longer life than the all-bronze wire (60 days compared to 30 days in continual operation).

However, when the cloth is woven entirely of stainless steel, it fails after only a few hours. Examination of these wires discloses that the failures are of the type discussed by HODGE and MILLER in their paper delivered before the 1939 Chicago Convention of the ⊕ on "Stress Corrosion Cracking of the Austenitic Chromium-Nickel Steels and Its Industrial Implications."

HODGE and MILLER stated that ethyl chloride, ferric chloride, and mercuric chloride solutions of wide concentration ranges are definitely effective in producing this type of failure. The matter is also summarized in "Critical Points" in METAL PROGRESS for August 1939, where other causes are noted by other metallurgists. I would like to add another medium as proven to have definite effect, namely, paper pulp liquor.

The annealing treatment necessary to remove the stressed state is practically prohibitive. The solution to the problem from the standpoint of the wire manufacturer is the material itself; among other users, the paper industry awaits a stainless steel immune to stress corrosion.

OTTO ZMESKAL
Department of Metallurgy
Massachusetts Institute of Technology

Calcium, to Purify Scrap
aluminum

NEW YORK CITY

To the Readers of METAL PROGRESS:

Metallic calcium, which up to the outbreak of the war was available to American customers only through importations, achieved a moderate use in the casting and refining of magnesium, aluminum, lead and steel. A note on this subject was printed in METAL PROGRESS, April 1932, by C. L. MANTELL and the present writer. The precipitation hardening of white metals by calcium was also commented upon by PAUL D. MERICA in the issue of January 1935.

Expansion of its use was hindered by limited production facilities in Europe. The outbreak of the war caused the immediate erection of a domestic plant to produce calcium and it is now available in commercial quantities.

The purpose of this letter is to bring to your notice the advantages of metallic calcium in reconditioning scrap aluminum. Almost all aluminum scrap contains alloying metals. While the addition of alloying metals to virgin aluminum is beneficial, these same metals when present in the scrap represent impurities which every smelter of secondary aluminum desires to eliminate.

It has been found that tin, bismuth, silicon, antimony and lead have an affinity for calcium. As calcium compounds these "impurities" thus formed are eliminated and enter the slag.

The great demand for aluminum is causing every kind of scrap to be collected for remelting, even scrap that heretofore on account of its combinations of metals was not considered worth paying any attention to. We believe that metallic calcium would be of great help to those remelting such scrap. The amount of metallic calcium required is comparatively small and, therefore, its use should be quite economical.

CHARLES HARDY

Dopes to Prevent Decarb

NEW YORK CITY

To the Readers of METAL PROGRESS:

In "Critical Points" last month the Editor discussed the action of copper paints to prevent decarburization and calls attention to the similarities and dissimilarities in the operations of bright hardening without decarburization and of casehardening (carburization). He asks the specific question, "Has anyone tried to spray the copper on with a metallizing gun?" I can answer that the gun has been used to a considerable extent to mask parts that must be soft after the casehardening operation.

In practice the parts are roughened by blasting and the portions to be hardened are covered with masking tape, allowing 1/8 in. around edges which are to remain soft. The bare portions are then sprayed with copper 0.010 in. thick, and the masking tape removed.

Typical results are as shown below. The S.A.E. 1020 steel was a 1 7/8-in. bar, and the 2 1/8-in. bar of "Max-El 1B" is Crucible Steel Co.'s low alloy machinery steel of carburizing type (0.20% carbon, high manganese, low molybdenum). After carburizing 9 hr. at 1700° F. the bars were quenched in water and the copper ground off.

	S.A.E. 1020	MAX-EL 1B
Quenched from pot	HARDNESS	
Protected areas	C-50 to 51	C-38 to 43
Beyond edge of above	C-67 to 71	C-62 to 65
Normalized at 1650° F. and quenched from 1450° F.		
Protected areas	C-30 to 35	C-20 to 25
Beyond edge of above	C-65 to 67	C-59 to 65

In such pieces a fairly sharp transition occurs from soft to hard areas, the Rockwell readings increasing 30 to 40 points in a distance of 1/16 to 1/8 in.

WILLIAM C. REID
Vice-President
Metallizing Engineering Co.

An Old Metallurgist's Notebook

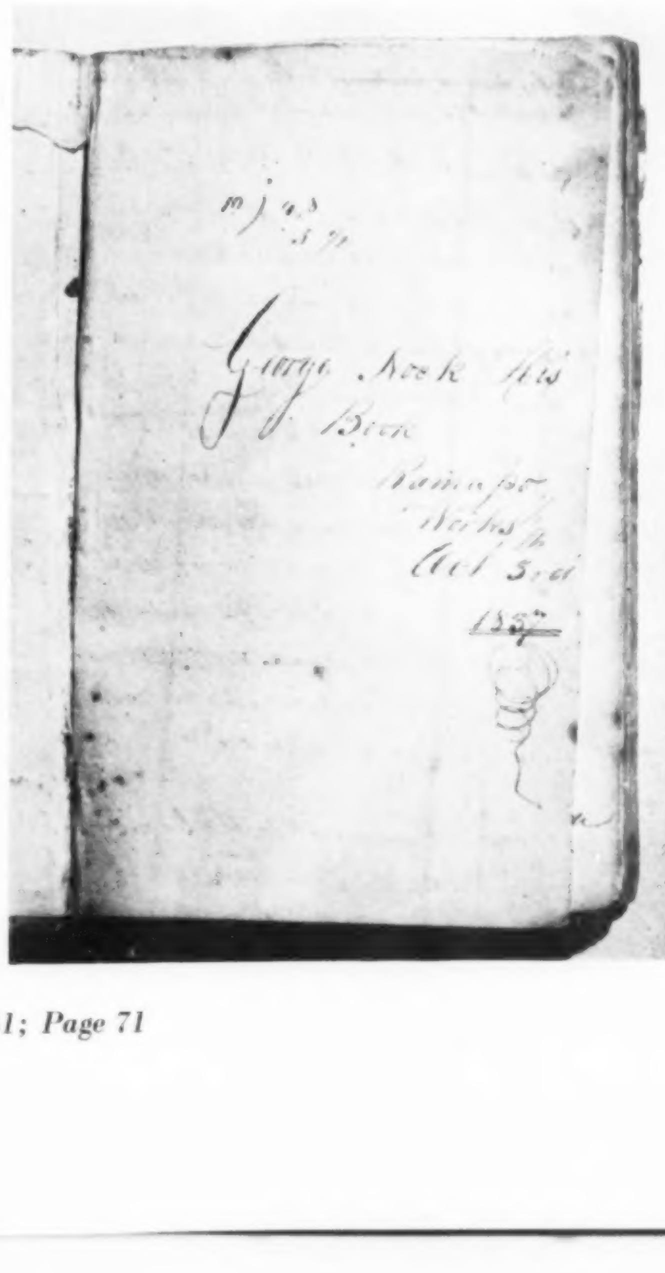
NEW YORK CITY

To the Readers of METAL PROGRESS:

A recent accession to the library of the American Iron & Steel Institute is a water-stained volume, like a surveyor's notebook, whose title page is photographed below.

Ramapo Works was built in 1800 in Rockland County, New York, just over the New Jersey border. Records show that in 1856 it contained bloomery fires, double furnaces for making steel, a forging hammer and rolling mill. About the time GEORGE NOCK compiled his book, 1837, spring steel was being made. Cast steel was first made there in 1854 from scrap steel and iron made in its own bloomery.

GEORGE NOCK does not describe himself in the book, but since it contains tables of weights of various shapes, methods of charging blast furnaces, sizes of oval plugs for turning rounds in guide rolls, speed of rolling mills, descriptions of various commercial designations of steel and methods of heat treatment, one would suspect he was the progenitor of our "sales metallurgist".



A note on railroad rails ("hardened" by tin, no less) indicates that even a few years after the Baltimore & Ohio Railroad had laid its first track, the Ramapo Works was interested in this business. Circa 1910 it was a leading producer of special track layouts, switches, crossings, and all sorts of track accessories.

One suspects from the context that most of the contents of the book was copied from articles or pamphlets NOCK had read, and thought would be later useful. Much apparently came from a current catalogue of Naylor and Co., British steel makers. Some excerpts on choice of materials and inspection probably will have a familiar ring even now. Worthy of repetition is his final paragraph, which is still true, no matter who wrote it or when:

"The great secret in steel making is to have the courage to be honest, a spirit to purchase the best material, and means and disposition to do justice to it in the manufacture."

JOHN G. MAPES

Excerpts From Nock's Book

Instructions for useing, tempering and hardening cast and other kind of steel.

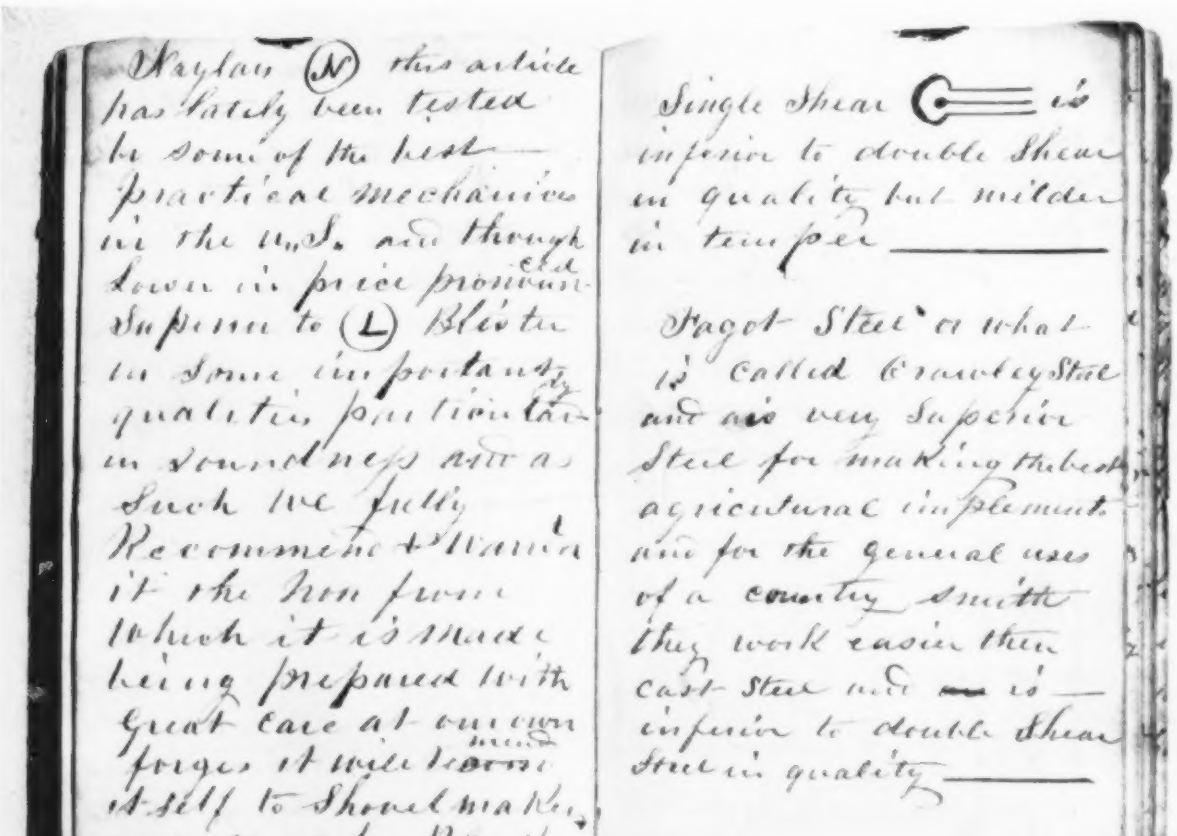
The manner of useing Blister Shear, Fagot and German Steel is so well known to every smith that it is needless to say much about them. The knowledge of useing cast steel is yet rather limited in extent and as this steel is the best for numberless purposes I give the following instructions.

A very clean fire is allways necessary, perfectly free from slag and dirt. The greatest care requisite in useing is never to heat the steel too hot. If once overheated it will throw out sparks and it is perfectly spoiled. If the burned part is broken the fracture will appear silvery and shining round the edge. A white heat must allways be carefully avoided. Great care must be taken to increase the heat gradually; if forced too much with the bellows the outer surface is made hot before the center, and if hammerd in this state the steel will be liable to crack. Never heat cast steel *hotter* than a *bright Cherry Red* by day light, or approaching to a white if in the dark. When finishing the forging continue to hammer planish until it is a black heat. This condenses the grain and improves it much for a cutting instrument but even here if hammerd too much at the black heat, fire cracks in hardening will be the consequence.

To Harden and Temper Cast Steel. For hardening cast steel, heat it to a Cherry Red as above and then plunge it into cold water; hard water is best. This makes it appear a dull dead white and is as hard as it can possibly be made.

To Let Down or Temper After Being Thus Hardened. If the article is large lay it on a slow coke or charcoal fire turning it over occasionally. You will perceive the white color gradually change to a yellow then brown and purple and finally a dark blue color. In this last state the steel is quite soft and may be filed easily. The general heat for tempering edge tools axes and etc. is between the brown and purple, say when purple spots begin to appear or about 600° Fahrenheit's thermometer. When the article attains the color which indicates the necessary temper, plunge it again in cold water withdrawing it instantly and lay it down to cool gradually. When cold it will be ready for use, or if it is an edge tool will be ready for grinding.

If the article which is to be tempered is very small, the best process will be to heat a strong bar of iron to a full red heat, then take it out of the fire and lay the steel article upon it, turning it over as above until



Naylor (N) this article has lately been tested by some of the best practical mechanics in the U.S. and though lower in price pronounced superior to (L) Blister in some important qualities particularly in soundness and as such we fully Recommend & Warrant it the iron from which it is made being prepared with great care at our own forges it will recommend itself to Shovel makers as well as for Black Smith

Single Shear is inferior to double Shear in quality but milder in temper

Fagot Steel or what is called Crawley Steel and is very superior Steel for making the best agricultural implements and for the general uses of a country smith they work easier than cast steel and is inferior to double Shear Steel in quality

the desired color appears on it. Then emmerse in water, withdrawing it instantly, and lay it down to cool. If the article has a very fine edge, as a penknife, etc., it is best to lay the thick part back upon iron, edge upwards. If the edge is allowed to touch the iron bar, it will become soft before the thick part is sufficiently lowered in temper. The properly tempering of steel is of the utmost importance and constitutes the chief value of edge tools and cutting instruments.

Nock on Inspection

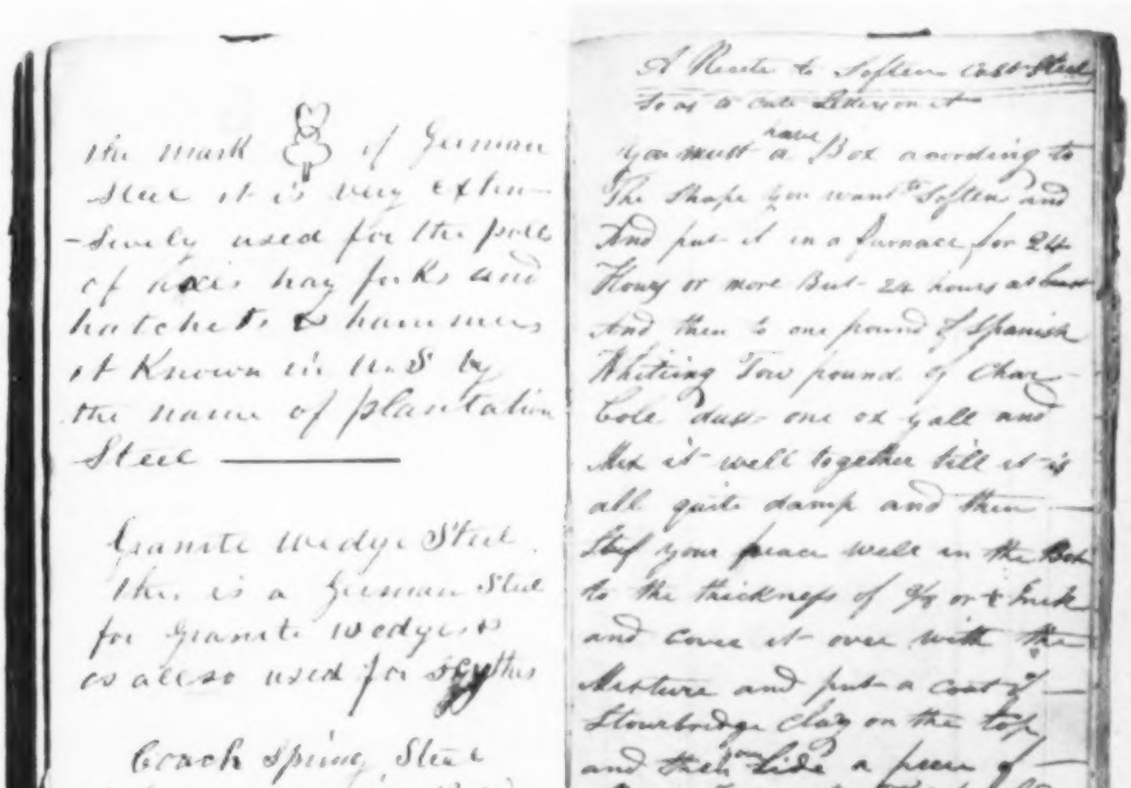
The best steel that can possibly be used for all and every purpose where a good article is intended to be made is decidedly cast steel in some of its sundry qualities which by proper management certainly excels every other kind and may justly be said to be the perfection of steel.

In the choice of steel bars there are a variety of opinions as to the best mode of ascertaining their comparative qualities. Some persons pretend to define this by suspending a piece of steel on a string and striking it with another, then according to the sound produced give their opinion of its merits. This is an incorrect method as the different density of the grain in sundry parts of the bar will very materially alter its conducting capacity for the reverberations of sound. This may also be affected by the smallest imaginable crack being perhaps at one end or near one end, too small to be perceived by the eye and yet amply sufficient to interrupt the uniform reverberations.

Other smiths in order to try the quality of a piece of steel will harden it and then fixing one end firmly will weight the other end until it either breaks or supports a certain weight. This method is not a correct criterian to judge by as much will depend on the compression of the grain either by the smith when working it or in the bar itself. For in every bar there will be found different states of compression of grain according as the parts were hotter or colder at the time of finishing the forgeing, and which if hardened without further hammering would be found to break with different weights.

On long experience, Naylor & Co. consider the best test of steel or the quality of steel is its appearance on breaking a bar. If the well known uniform steel-gray surface is exhibited, free from white or silvery specks, and the fracture is tough conchoidal — not short or brittle — an artizan may purchase it with confidence as being good steel. To examine for flaws, fix one end of the bar firmly and with a powerful winch at the other end subject it to tortion and then reversion. If there are any longitudinal flaws they will now be exhibited. To search for transverse flaws subject the bar to extensive flexure on each plane of the surface. If these kinds of flaws exist they will now be rendered visible.

Naylor on Steel. In the cementation of blister steel they use a pyrometer by which they regulate the specific heat necessary for each quality of steel and maintain it uniformly for any length of time in their furnaces, thus securing an invariable equality of temperament throughout. Their cast steel was some times complained of for being flawy and unsound. Analytical inquiry has exhibited the facts that these faults are caused by refractory internal surfaces of the blisters which are produced during the process of cementation. In refining their steel, Naylor has introduced a reagent into their melting crucibles which reduces these ferruseted cyanides to simple carburets and thus produces a perfectly sound steel. The heat at which their cast steel is fused for casting is so perfectly uniform that all the ingots are as one in grain and texture and cohesion and all carbureted in the same proportion.


the mark of German
Steel it is very exten-
-sively used for the pole
of axes hay forks and
hatchets & hammers
it Known in U.S by
the name of plantation
Steel

Granite Wedge Steel
this is a German Steel
for granite wedges is
also used for Scythes

Coach Spring Steel
of London quality Rolled
Smooth particularly on the
Edges & prime for Rail Road Cars

A Recete to Soften Cast Steel
So as to cute Letters on it
you must have a Box according to
The Shape you want to Soften and
And put it in a furnace for 24
Hours or more But 24 hours at least
And then to one pound of Spanish
Whiting Tow pound of Char-
cole dust one ox gall and
Mix it well together till it is
all quite damp and then
Stuf your peace well in the Box
to the thickness of 3/4 or 1 inch
and Cover it over with the
Mixture and put a Coat of
Stourbridge Clay on the top
and then your Lids a peace of
Sheet Iron on the Top for Lid
Iron about 3/16 will do for Box

Wrought Iron Viewed as an iron-phosphorus alloy

PITTSBURGH, PA.

To the Readers of METAL PROGRESS:

You may be interested in having the views of one long associated with a large manufacturer of genuine wrought iron in America on the subjects considered by O. A. TESCHE in his letter of the above title in METAL PROGRESS for March.

We are in agreement that until the long existing rivalry between wrought iron and steel is definitely settled by future generations, efforts should be made to establish facts and supporting data by laboratory tests. In this vein of thought, we do not believe, as some are prone to do, that the laboratory evidence thus far established necessarily tells the whole story for evaluating materials for service. Usage experience should, and we think always will, be a guide for the selection of materials.

Consider in this connection the history of laboratory fatigue testing: The earlier work developed data displaying endurance limit values when tested in dry air. Later testing showed that endurance values obtained by testing pieces bathed in mildly corroding liquids gave different values. Recently, the deciding effects of notch and damage by overstrain have been isolated by laboratory tests. Hindsight is better than foresight, and these later developments in evaluating the simultaneous effects of corrosion, notch, and overstrain on fatigue values certainly make it crystal-clear today how far wrong we could have been if the laboratory data covering fatigue testing in air were used as a sole and definite yardstick for evaluating materials for services where fatigue is involved, coupled with corrosion, nick effects, and occasional overstrain. The question may well be asked: Have our laboratory tests and investigations up to the present time uncovered all the essential phases which may have a bearing on behavior of metals in services involving fatigue?

Our thoughts with reference to phosphorus do not seem to agree with those of Mr. TESCHE. Admittedly, the phosphorus (that portion not identified as P_2O_5 in the slag component) is alloyed with the metal. However, in this respect the phosphorus in wrought iron is no different in its alloying behavior or effects than phosphorus in mild steel. There does not seem to be any substantial reasons for believing that whatever merits wrought iron may have, they are the result of this iron-phosphorus relationship. In this connection, the dilatometer curves which have been used as supporting evidence may show that wrought iron with 0.17% phosphorus does have a more suppressed alpha-gamma transformation than ingot iron with phosphorus under 0.01%, but does it necessarily follow that the relative suppression of alpha-gamma transformation is an index of toughness or corrosion resistance?

In conclusion, we would like to call attention to the opening sentence of Mr. TESCHE's letter, in which he says "wrought iron has all but disappeared from the American industrial scene"; but in his country (Transvaal) it is still a metal of industrial importance. Either he does not keep posted on American production statistics or the production of wrought iron in Transvaal is far beyond our fondest dreams. Our company alone produces 100,000 or more tons of wrought iron annually.

EDWARD B. STORY
Supervisor of Chemical and
Metallurgical Departments
A. M. Byers Co.

Prize Papers on Arc Welding

CLEVELAND, OHIO

To the Readers of METAL PROGRESS:

I have noted with interest the announcement by the Summerill Tubing Co. of Bridgeport, Pa., of the establishment of a series of prizes for papers to advance the art of welding of aircraft steels, including tubing and other steel parts for tubular assemblies.

My purpose in writing you is to point out that papers submitted in the Summerill contest will also be eligible in the $200,000 Industrial Progress Award Program which is being sponsored by the James F. Lincoln Arc Welding Foundation, provided of course that such papers comply with the Foundation's rules and conditions as regards subject matter and form.

It is conceivable that a paper entered in the Summerill contest would be written in such a way as to be acceptable in the Lincoln Program. If it is not acceptable as written, the author, by a few changes or additions, could make it conform to the Foundation requirements. Eligibility in the two projects should provide added stimulus to the study of welding in the aircraft field.

ED C. POWERS
Assistant Secretary
The James F. Lincoln Arc Welding Foundation


...Molybdenum makes possible heat
check resistant base iron brake drums

PERSONALS

E. J. Hergenroether has resigned as metallurgist, Detroit Field Office, Development and Research Division, International Nickel Co., Inc., to join the staff of the Conservation Section, Production Division, Office of Production Management, Washington, D. C.

A. F. Dohn, formerly vice-president in charge of toolsteel sales, Allegheny Ludlum Steel Corp., has retired from active business interests but will continue in a consulting capacity as a vice-president of the company.

C. R. Cox, formerly vice-president in charge of operations, National Tube Co., Pittsburgh, has been elected executive vice-president.

Frank T. Sisco, formerly editor of the Alloys of Iron Research of the Engineering Foundation, has been appointed assistant secretary of the American Institute of Mining and Metallurgical Engineers and secretary of its Iron and Steel and Institute of Metals Divisions, succeeding **Louis Jordan**, who is now in the Government service in Washington. **John S. Marsh**, formerly physical metallurgist and associate editor of Alloys of Iron Research, is now editor, succeeding Mr. Sisco.

Francis T. McGuire, teaching fellow in the department of metallurgy at University of Notre Dame, received the degree of Doctor of Philosophy, and is now assistant professor of metallurgy in the University of Kentucky, Lexington.

H. E. Doughty has been appointed manager of the recently established Philadelphia branch of the Jessop Steel Co., Washington, Pa.

Herbert J. Braun, formerly with Foote Bros. Gear and Machine Corp., Chicago, has been appointed Detroit sales representative for McKenna Metals Co., Latrobe, Pa.

Transferred by Carnegie-Illinois Steel Corp.: **G. A. Whitehurst**, from Chicago district industrial engineer to assistant to chief engineer of the company in Pittsburgh. **G. S. Mican**, formerly superintendent of structural and blooming mills, has been appointed assistant division superintendent of rolling at Carnegie-Illinois's South Works.

Joseph Wesley has resigned as plant metallurgist, General Motors Truck & Coach Division, Pontiac, Mich., to take a position as industrial engineer in the Metal Cleaning Division, J. B. Ford Sales Co., covering New York State territory.

PERSONALS

John A. Comstock has been made metallurgist, Pratt & Whitney Aircraft Division, United Aircraft Corp., E. Hartford, Conn.

Transferred by General Screw Mfg. Co.: **E. G. Wertheimer**, metallurgical and sales engineer, to the main plant at Chicago.

C. B. Voldrich, formerly associate materials engineer, Office of Supervisor of Shipbuilding, U.S.N., Newport News, Va., is now welding engineer at Battelle Memorial Institute, Columbus, Ohio.

Norman L. Deuble, formerly assistant to vice-president, Copperweld Steel Co., Warren, Ohio, has been appointed manager of sales.

Appointed to Allegheny Ludlum Steel Corp.'s newly formed Committee for Conservation of Strategic Materials: **V. B. Browne**, vice-president in charge of research; **C. A. Scharschu**, director of research and metallurgy (both at the Brackenridge, Pa. plant); **R. P. De Vries** and **W. R. Breeler**, associate directors of research at the Watervliet and Dunkirk, N. Y., plants respectively.

Promoted by Stoody Co., Whittier, Calif.: **J. R. Spence**, from industrial sales and research manager to general sales manager.

Alden F. Erikson, district manager of sales for Wyckoff Drawn Steel Co. in the Boston and New England territory, has been called for active duty as major, 68th Coast Artillery Anti-Aircraft Regiment. **Theodore C. Cederholm,** formerly with the Hawkridge Brothers Co., has been named to succeed Major Erikson as district sales manager.

Fred J. Kuder is methods engineer with Seaboard Commercial Corp., New York City, acting as chief inspector at Samson United Corp., Rochester, N. Y.

John R. Fulton, formerly in the Detroit office of Wheelock, Lovejoy & Co., Inc., is now assistant to the vice-president at the main office in Cambridge, Mass.

Edwin T. Myskowski is now employed in the Division of Physical Metallurgy at the Naval Research Laboratory, Anacostia Station, Washington, D. C.

W. C. Dyer, formerly employed in the Metallurgical and Inspection Department of the Colorado Fuel and Iron Corp., Pueblo, Colo., has accepted a position with the War Department, St. Louis Ordnance District, in charge of inspection of ordnance materials in the Tulsa, Okla. district.

PERSONALS

Transferred by the Bristol Co.: **Donald C. Sanford** ⊕, from sales engineer in Philadelphia to resident sales engineer for the State of Connecticut.

Emery B. Gebert ⊕ is employed by the Amplex Division, Chrysler Corp., Detroit.

James S. Rennick ⊕ has been promoted from tool supervisor, Homestead Steel Works, Carnegie-Illinois Steel Corp., to treatment foreman, U. S. Naval Ordnance Plant, Charleston, W. Va., operated by Carnegie-Illinois.

Robert Brown ⊕, formerly with Emsco Derrick & Equipment Co., is now working in the engineering department of Unit Rig & Equipment Co., Tulsa, Okla.

G. E. F. Lundell, chief, Chemistry Division, National Bureau of Standards, Washington, D. C., has been elected president of the American Society for Testing Materials. **E. W. Upham** ⊕, chief metallurgist, Engineering Department, Chrysler Corp., Detroit, has been elected as a member of the Executive Committee.

Joseph B. Kushner, metal finishing consultant and engineer, has moved his offices and laboratories to larger quarters at 114 E. 32nd St., New York City.

Carl B. Christensen ⊕, formerly in the Research Division, Talon, Inc., is now in charge of production for Casco Products Corp. defense program.

Everett C. Westerfield ⊕ is now in charge of the Physical Testing Laboratory at the Long Beach plant of the Douglas Aircraft Co.

J. A. Snyder ⊕ has left the University of Illinois and is metallurgist, Technical Division, Engineering Department, E. I. du Pont de Nemours & Co., Wilmington, Del.

Robert S. Harper ⊕, formerly with Farrel-Birmingham Co., Ansonia, Conn., has been called to active duty at the Naval Gun Factory in Washington, D. C., as assistant to inspector of materials.

Milton Wilker ⊕, formerly tool designer with Rochester Products Division, General Motors Corp., is now with Air Associates, Inc., Hasbrouck Heights, N. J., working on the design of small motors for aircraft applications.

James Colasanti ⊕ has been called to active duty as 1st lieutenant, Ordnance Department, and is stationed at the Denver Sub-Office of the St. Louis Ordnance District.

PERSONALS

Transferred by Handy & Harman: **A. M. Setapen**, from the Bridgeport, Conn., plant, where he has been in charge of the activities of the American Silver Producers Research Project, to the New York office as sales and development engineer in the Industrial Engineering Division.

Transferred by Youngstown Sheet & Tube Co.: **E. G. Brick**, from Detroit District Office on metallurgical contact and development work to the Alloy Sales Office in Chicago.

Kenneth A. Stroble, sales engineer, Latrobe Electric Steel Co., Detroit, is now 1st lieutenant, Ordnance Department, stationed at Springfield Armory as assistant to officer in charge of production.

George E. Linnert has left Republic Steel Corp., Chicago, to accept a position as metallurgist with the Rustless Iron and Steel Corp., Baltimore.

Transferred by International Harvester Co.: **P. H. Daily**, assistant metallurgist, from the Farmall Works, Rock Island, Ill., to the West Pullman Works, Chicago.

Clarence W. Fabel has been transferred from assistant metallurgist, Naval Gun Factory, Washington, D. C., to associate materials engineer, Materials Section, United States Maritime Commission, Washington, D. C.

N. C. Fick has been transferred from the United States Steel Corp. Research Laboratories, Kearny, N. J., to the Metallurgy Department, Gary Works, Carnegie-Illinois Steel Corp.

Bernard R. Queneau, assistant professor of metallurgy, Columbia University, has been given a leave of absence to go on active duty with the Navy, assigned to the U. S. Naval Proving Ground at Dahlgren, Va.

Arthur N. Armitage, engineer of tests, Columbia Steel Co., Torrance, Calif., is on extended active duty as Major at Watertown Arsenal.

Bruce E. Warner has been ordered to active duty with the 68th Coast Artillery at Camp Edwards, Mass., acting as executive officer of "G" Battery.

William H. Snair, formerly with American Can Co., Research Department, Maywood, Ill., has been called to active duty as 1st lieutenant, Ordnance Department, serving at Springfield Armory, Springfield, Mass.

Robert F. West is now draftsman, Newport News Shipbuilding & Drydock Co., Newport News, Va.

AIRCRAFT

(Continued from page 42)

the change of shape now occurring when the drawn section is pre-stretched. Other future possibilities may be the use of extrusions prestressed by the aluminum mills and by the use of 24S-T or 24S-RT strip stock for rolled sections. The latter is beyond the promotional and design stages, since manufacturers claim that the bend radii necessary for aircraft sections can be obtained on modern rolling machines. The chief hitch now appears to be the shortage and high cost of the stock. A price differential of 6¢ per lb. now exists on 24S-T stock, and the 24S-RT strip, while not now available commercially, can be delivered on 3 months' notice at a premium of 25¢ per lb. (Rapidly changing prices and deliveries may now have affected these figures.)

We, at Consolidated Aircraft, now prestretch our drawn structural sections to 3½% permanent set on the straightening jig almost as rapidly as we could straighten them to ½%, and with negligible extra cost. Could not the aluminum manufacturers do this same prestretching in the straightening operation? It would thereby provide an old material with new properties and an increased strength-weight ratio.

The expectations I have tried to build up might crumble a little when one recalls Table 1 showing that the 50,000-lb. airplane has only 1500 lb. of drawn structural sections, and 500 lb. of extrusions. It must fairly be stated that the weight saving may be only 10% of this 2000 lb., or 200 lb. Engineers now worry about 1/10-lb. increments in weight reports, yet the Army and Navy Air Services may, at the same time, add 50 lb. of fixed equipment or another crew member as afterthoughts!

When can "cold working", as discussed above, be justified? Possibly only when weight control is as important on *each unit* of an airplane as it is now considered to be in aircraft structures.

In summary, therefore, it is believed evident, by the foregoing experiments and production use, that the pre-stretching of aluminum alloy shapes and extrusions is a practical production procedure, affecting a material gain in physical properties and weight saving, without loss in factory assembly time.

STAINLESS

(Continued from page 62)

is possible to do so. Scruff from metal working tools will later cause discoloration. Any foreign material adhering to the surface can under some conditions aid in the destruction of the passive surface film necessary to the corrosion resistance of stainless steel. After degreasing and other cleaning, a dip or a scrub with nitric acid is the best final operation.

Mechanical work, such as machining and bending that result in the cold working of certain areas of metal and leave these cold-worked regions in contact with relatively strain-free areas, may set up internal stresses that enhance corrosion, sometimes in rather mild surroundings. Cold work should therefore be followed by annealing in order to relieve locked-up stresses and insure best corrosion resistance. This, however, is not necessary in all conditions of service.

In Types 308 and 317 heating into the range of temperatures from 800 to 1600° F. results in the precipitation of harmful carbides in the metal, the more the longer the metal is in that range of temperature, and renders it correspondingly susceptible to intergranular corrosion under some severe conditions of service.

In closing, it might be well to refer briefly to a new development which might be of some value to the paper industry. Due mainly to the ease of fabrication, the austenitic alloys such as No. 308 and 317 have been used to a much greater extent than the ferritic high chromium alloys which are equally as resistant to corrosion. The two most important of these alloys are the straight chromium-iron alloys of 25 to 30% chromium, and Type 329 mentioned before, which contains small quantities of additional elements such as molybdenum and nickel.

The use of these alloys has been restricted because they are extremely difficult to process as well as to fabricate; likewise they become very brittle when welded or heated within the range of temperature encountered in stress relieving and annealing. The recent development of Allegheny Ludlum's new melting process called "Pluramelt" described in METAL PROGRESS, February 1940, by which various compositions can be intermelted, is correcting this situation. By making plate with a thin facing of high chromium alloy and a thick backing of low carbon steel, we may take advantage of the corrosion resistance of the one alloy in combination with the highly desirable physical properties of ordinary steels.

OXY-ACETYLENE FLAME-PRIMING makes paint go on faster and last longer . . .

1. What it is and does

Oxy-acetylene flame-priming is performed by passing the flame from an Oxweld heating head over structural steel before the first protective coating is applied. The quick heat causes rust and loose scale to pop off, and drives out the surface moisture, thus leaving a clean, dry surface for the paint. Structures of any size or shape can be flame-primed in the shop or on the job.

2. How it helps

Flame-priming is followed by wire-brushing, and close behind this comes the painting. As a result the metal is clean, dry, and still warm—making the paint go on faster, bond tighter, dry quicker, and last longer.

3. What you need to use it

All you need to use this method is an Oxweld W-26 heavy-duty welding blowpipe and an Oxweld flame-priming head, connected to an adequate source of oxygen and acetylene supply. Any operator can learn the technique quickly.

With standard welding heads, you can use your flame-priming equipment for heavy welding, and for straightening, forming, and other heating operations.

and Linde can help you use it!

Linde can supply the gases, the apparatus, and help in using flame-priming. If you are interested in giving longer life to paint jobs—or if you are confronted with bottlenecks in using sand-blasting equipment—*talk it over with Linde!*

THE LINDE AIR PRODUCTS COMPANY

Unit of Union Carbide and Carbon Corporation

General Office: New York, N. Y. UCC Offices in Principal Cities

In Canada: Dominion Oxygen Company, Limited, Toronto

LINDE OXYGEN . . . PREST-O-LITE ACETYLENE . . . UNION CARBIDE
OXWELD, PUROX, PREST-O-WELD APPARATUS . . . OXWELD SUPPLIES

The words "Linde," "Prest-O-Lite," "Union," "Oxweld," "Purox," and "Prest-O-Weld" are trade-marks of Units of Union Carbide and Carbon Corporation.

DIE CASTINGS

(Cont. from page 67) die castings as well as for other parts now manufactured from rod stock and required in lots of many millions. Approvals for the use of zinc base die castings in fuses will only be forthcoming after satisfactory showings of sample parts in firing tests at Aberdeen Proving Grounds under extreme temperatures ($-50°$ F. to $+170°$ F.), and then only when definite assurance can be had of uniform quality. Premature explosions of projectiles or failure to explode at the proper time are two faults for which mass production methods are not considered adequate compensation.

It would appear that the only zinc die castings suitable for use in ordnance are those made with 99.99+% zinc and kept free from lead and tin contamination in melting and casting so as to insure stability of size and properties. For example, Navy Department Specification 46Z2 specifies that only A.S.T.M. No. 23 alloy may be furnished, and the impurity limits necessitate the use of either virgin metal or approved high grade scrap with all compositions controlled by spectroscopic analysis.

A recently approved Army-Navy Aeronautical Specification (AN-QQ-A-366) which covers aluminum die castings for instrument cases permits the use of any one of three alloys (*A*, 5% silicon, 4% copper; *B*, 12% silicon; or *C*, 8% magnesium). Specified physical, chemical and X-ray tests call for high quality castings. Army Air Corps design instructions do not bar the use of die castings from structural parts but specify that its calculated stress must not exceed 15% of its tensile strength. Even on rocker box covers, castings must be free from porosity. Consideration is being given to the liberalization of impurity limits in specifications for aluminum alloys, but quality control will be insisted upon.

Additional fields for die castings in defense production exist in Army transportation units, ships and Quartermaster supplies, as well as new cantonment construction. With the magnitude of the defense program, the total die casting output should be increased rather than diminished, if the industry will apply itself aggressively to the problem of selling the defense procurement agencies.

HARVEY A. ANDERSON
Technical Consultant to OPM
on Die Castings

QUENCHING STRESSES IN ALUMINUM*

By A. von Zeerleder

WITH the introduction of heat treatable aluminum alloys, quenching stresses became important. HEYN and BAUER first studied exhaustively the stresses induced by working, and SACHS improved their methods by considering the radial and tangential stresses, as well as the axial ones. GROGAN and CLAYTON studied the quenching stresses in "Y" alloy, duralumin, and 25-S. PHILLIPS and BRICK investigated radiographically the effect of the quenching speed and copper content. WASSERMANN studied change in the lattice and found that the stresses remained constant in round bars over ¼ in. The radiographic work of BRICK, PHILLIPS and SMITH, on quenching stresses and age hardening in aluminum-magnesium alloys, must also be mentioned.

The present studies relate to Avional D (4% Cu, 0.2% Si, 0.6% Mg, 0.5% Mn, 0.2% Fe, balance Al). Extruded bars of 2-in. diameter were tested, made from 8-in. billets cast in ordinary iron molds.

Maximum heat stresses occur after quenching; during rapid cooling the thermal expansion of the material is suddenly reversed. In a round billet, the outer layer cools more quickly than the core and shrinks on the center which has not yet begun to contract. Thus the outer layer is submitted either to elastic strain or to overstraining. Subsequently the core cools, and a state of equilibrium is next set up between the stretched outer zone and the compressed core. With further cooling of the core the stresses reverse; the contraction of the core continues and it is thereby subjected to tension; the outer layer will therefore be under compression.

The magnitude of these internal stresses largely depends on the physical properties of the quenching medium — that is, its cooling power. In addition, the coefficient of expansion, temperature, thermal conductivity, and specific heat of the quenched material have some effect. WASSERMANN found that 0.04-in. round pieces of pure aluminum are almost free from strains, but with increasing diameter the stresses reach a maximum of 8000 psi. at about ¼ in. diam-

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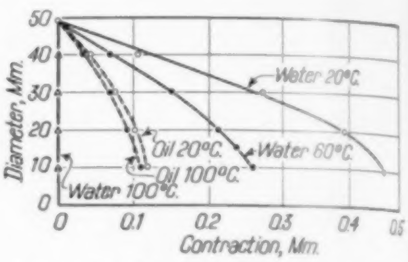
eter, but the present investigation does not check this general tendency.

In the tests described the internal strains were measured by HEYN and BAUER's method of turning off small layers of metal and measuring changes in length. Figures so obtained are too low, since the method takes into consideration only the unidirectional longitudinal strain.

Influence of cooling before quenching was studied — also the temperature and the nature of the quenching medium, and the influence of cold work before or after age hardening at 70° F. The stresses also diminish somewhat with increasing time of cooling prior to quenching.

The greatest strains appear at 70° F., the lowest temperature of the quench tested. In warmer quenches at 120 to 140° F. the strains have already diminished markedly, while quenching in



Effect of Different Quenching Media on the Contraction in 1¼-In. Bars After Turning Off Successive Surface Layers. Bars annealed 2 hr. at 970° F., aged 24 hr. at 120° F.

boiling water causes no measurable strains. Oil quenching is also mild in its effects, and they are practically independent of the temperature of the oil.

An important reduction of internal strains occurs after 2% cold stretching before or after aging at room temperature. In the core the stresses are even reversed. A similar effect is caused by 1% upsetting after aging; a definite reversal of the strains in the outer layer then occurs.

One difficulty with the elimination of strains by heat treatment (tempering) is that this may cause undesirable changes in strength or corrosion resistance. There remains, therefore, the method of removing the internal stresses by subjecting the piece to a small deformation of another kind. With drawn materials this procedure can be combined with the straightening. For this operation uncoiling machines and inclined-roll straightening machines are used; in this way the compressive stresses in the outer layer are reduced or even transformed into tensile stresses. It is also possible to reduce the internal strains by bending or hammering, or by subjecting the pieces to compression in a liquid.

FLAKES IN FORGINGS

Abstracted from The Metallurgist, *Feb. 28, 1941, page 4.*

THERE IS SOME evidence that "flakes" are not discontinuities. A general decrease in their area, with corresponding improvement in tensile strength and elongation, results from the increased degree of crystalline refinement produced by heat treatment. Discontinuities would not be expected to heal in this manner. This type of defect has been found in practice to follow, usually, overheating of the piece.

As opposed to this type of flake, which FOLEY regards as the genuine variety, another defect (more accurately described as a cooling crack) appears in metal. Operations which result in the coarsest grain structure produce the greatest tendency toward the development of these cooling cracks. FOLEY believes, however, that they can be welded up, and there is therefore no stage at which hot working will not fully correct this type of defect. The temperature range in which internal cracking occurs is probably different for different compositions of steel.

Such defects have been practically eliminated by using a controlled rate of cooling. While relatively high carbon steels may be more susceptible to cooling cracks, the greatest trouble has been experienced with the low alloy chromium, chromium-molybdenum, nickel-chromium and nickel-chromium-molybdenum steels. The basic electric furnace, in FOLEY's opinion (*Metals and Alloys*, October 1940), produces the greatest proportion of flaky steel; there is considerable authority for the statement that acid steel is less prone than basic to develop defects of this type and, in fact, FOLEY states that he has yet to encounter flakes in acid steels.

A large part of the trouble arises in the production of alloy steel forgings of large section. Susceptibility appears to start in sections of 2 to 3 in. Smaller sections rarely, if ever, develop flakes under normal conditions, which is consistent with the fact that they do not occur in the outer inch or so of surface metal.

These facts regarding size of section do not appear to fit in logically with the use of a slow cooling rate for their elimination, since the defects are not found in the smaller sections and the outer layers, which cool most rapidly. However, this anomaly

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may be explained if the effect is due to hydrogen, held in solid solution in the steel down to "black heat", and then suddenly liberated. Undoubtedly hydrogen in sufficient amounts will cause cooling cracks, yet even in such cases controlled cooling will entirely prevent their occurrence.

While it has not been shown that hydrogen is the only factor which will render steels susceptible to this defect, its elimination as far as is practicable during melting is a step in the right direction. ZAPFFE and SIMS in a series of articles in the same publication list the main sources of hydrogen as moisture in combustion air, rust on scrap and mill scale, lime, and ferro-alloys.

They make the following recommendations:

1. Select a charge that is free from moisture and rust. The lime should be carefully dried and stored in moisture-proof containers. Ferro-alloys, especially if they are to be added late in the heat or in the ladle, should be dried before using.

2. In processes requiring a draft or blast of air, dry the air.

3. Use a vigorous boil lasting about 1 hr. (as recommended by Russian metallurgists). The rate of carbon elimination should not be less than 0.1% per hr. The acid openhearth will perhaps permit a rate of 0.2 to 0.3% per hr. without over-oxidizing the melt. A total elimination of 0.5% is optimum. High temperatures are recommended by the British.

4. Shorten the refining period. Avoid late additions to the bath. Tap at the lowest feasible temperature, according to the British and the Germans.

5. Avoid mold washes that contain hydrogen. The shape of the mold is without influence.

6. Pour slowly and prevent splashing and foaming. Bottom pouring is recommended.

7. Strip the ingots at about 1100° F. and place them in the soaking pit until they are uniformly heated to the forging temperature; or, if they are not to be forged immediately, bury them after stripping in ashes, slag wool, charcoal dust, or some other insulating material, and let them cool slowly almost to room temperature. Some hot working before cooling is beneficial.

8. After forging, cool the material in the manner just stated, being particularly careful that the cooling rate is exceedingly slow through the temperature range where the steel is no longer plastic. This precaution is important, not only because both the solubility and diffusibility of hydrogen decrease with decreasing temperature, but also because internal stresses are only slowly relieved below 700° F.

STRATEGIC METALS

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Antimony — Work has been under way since 1917 on an Idaho gold ore that is penalized severely by copper smelter schedules on account of a 15% antimony content in the concentrate. Antimonial ores of this type can be sent to lead smelters to produce antimonial lead; but for producing pure metallic antimony a process such as is described below is applicable, and is now ready for semi-commercial trials.

The general scheme is to produce a crude antimony bullion containing the precious metals and to refine this electrolytically to give antimony at the cathode and collect gold and silver in the slimes. About 85% of the arsenic in the raw concentrate is removed by roasting at 900° F. in a steam atmosphere. These calcines were smelted with iron, and slag and lean matte separated from the "metal" which contains 60 to 80% Sb. Anodes cast of this metal are electrolyzed in a sulphate-fluoride bath, the cathodes from which contain 98.5% antimony and 1.5% arsenic (which can be eliminated, if necessary, by fusion under sodium salts).

Nickel — Ores containing ½% of both nickel and copper are found in Nevada, and a treatment has been worked out to a point that would justify semi-commercial scale tests when assurance is given of an adequate deposit. These ore bodies are now being explored by the Section on Investigation of Domestic Sources of Strategic Minerals. The process is a simplification of the one used in the Canadian nickel plants.

Flotation of the ore produces concentrates containing 4.6% Ni, 6.1% Cu and 26.0% Fe which can be smelted directly to matte. The iron and sulphur is then blown out (slagged) in a basic converter and the converter metal — principally nickel and copper — is cast into anodes for electro-refining. A portion of the converter metal is leached to produce electrolyte. Copper is recovered in the first electrolytic cells, using the converter metal as soluble anodes. The nickel concentration in the electrolyte builds up as the copper is plated out, and the electrolyte is finally stripped of copper. The high nickel electrolyte then goes through a purification system, in which all detrimental impurities are removed and the resulting nickel solution is fed to the nickel cells.

The products of the process are electrolytic copper, electrolytic nickel, and anode slimes containing all of the precious metals. *(Continued on page 122)*

MAGNESIUM

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While the production of magnesium from chloride brines is well known, another generous source of the metal is in the carbonate, magnesite.

Distillation — Experimental work has been based upon general information concerning a process said to be in commercial operation in Austria, and described as follows: Calcined magnesite of high purity is mixed with one third its weight of coal or coke. The pulverized mixture is fed continuously between the electrodes of a three-phase electric furnace in which the arc strikes a carbon bottom. The entire charge is volatilized, and the gaseous product escapes through a flue, where it is "shock-chilled" by injecting 6000 cu.ft. of hydrogen per lb. of metal reduced. Even this drastic cooling and dilution does not prevent much reoxidation.

The condensate is a superfine powder containing 60 to 70% metal, 7% carbon, 15% magnesium oxide, and silicides or carbides of the impurity metals. It is collected in a cooler and filter system, mixed with residues, passed through a briquette press, and then redistilled in an electrical resistance furnace heated to 1650° F. and evacuated to 0.03 atmosphere. As the condensate is violently pyrophoric, all these operations must be carried out in a hydrogen atmosphere. The hydrogen is passed through a regenerating plant to remove carbon monoxide, and the cooled, purified gas is returned to the furnace for repeated cycles.

In studying this process the most important innovation made by the Bureau's researchers is the use of a light distillate fuel oil to spray and condense the metal vapor. It requires only 7 or 8 gal. of oil per lb. of magnesium, and most of the oil is recoverable for re-use. The condensate is collected in a centrifugal separator as a thick mud, which can be exposed to air safely.

Lack of information regarding the foreign technique forced the Bureau investigators to develop the following details:

1. A gas-tight arc furnace operating at 4000° F.

2. Refractories to resist disintegration at 4000° F., and adequate thermal and electrical insulation.

3. A hydraulic feeder to inject a pulverized mixture into the furnace at a controlled rate through a sealed port.

4. Regulation of the power input to the arc furnace to produce a reaction rate exactly equivalent to the rate at which feed is supplied.

5. A special spray nozzle to atomize the oil.

6. Control of the temperature

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in the separator by regulation of the rate at which the oil is circulated.

7. A cyclonic separator to remove the condensate from the gaseous products.

8. A continuous, two-stage distillation furnace to recover oil and refined metal from the crude condensate.

Laboratory tests of this revised process have been completed, samples of refined metal produced, and the data required to design a larger unit have been obtained. Extensive tests in large equipment provided with automatic operations and controls will determine the technical and economic feasibility of this attractive process.

Conversion of Carbonate Into Chloride

The present standard method for producing magnesium metal by electrolysis of a fused mixture of $MgCl_2$ and NaCl is better adapted to salts derived from brine than to magnesite as a raw material.

It is possible, however, to convert calcined magnesite directly to chloride by heating it with carbon in a chlorine atmosphere. The product may be electrolyzed to magnesium metal and chlorine, and the chlorine can be used cyclically. The reaction can presumably be accomplished by passing chlorine through a heated bed of a briquetted mixture of carbon and calcined magnesite or by atomizing the pulverized mixture into a heated chamber with chlorine gas.

No method in which the reactor is externally heated appears to be feasible for use on a large scale. Difficulties in forcing chlorine through impervious briquettes led to the development of means for feeding ore, carbon, chlorine, and air at controlled rates through an atomizing burner into a small shaft furnace, heated by the combustion of the excess carbon. A high conversion was accomplished in one such furnace that operated continuously over a long period.

The magnesium chloride produced contained calcium chloride, carbon and silicon as impurities. When this material was electrolyzed in the usual type of cell (with submerged cathode) the metal always contained inclusions of the electrolyte.

To avoid this difficulty, a cell with a floating cathode (of the type used for making electrolytic calcium) was tested. The metal produced in this cell was exceptionally clean with virtually no inclusions. Spectrographic comparisons showed slightly more impurities than Dow redistilled metal, but less than ordinary electrolytic magnesium.